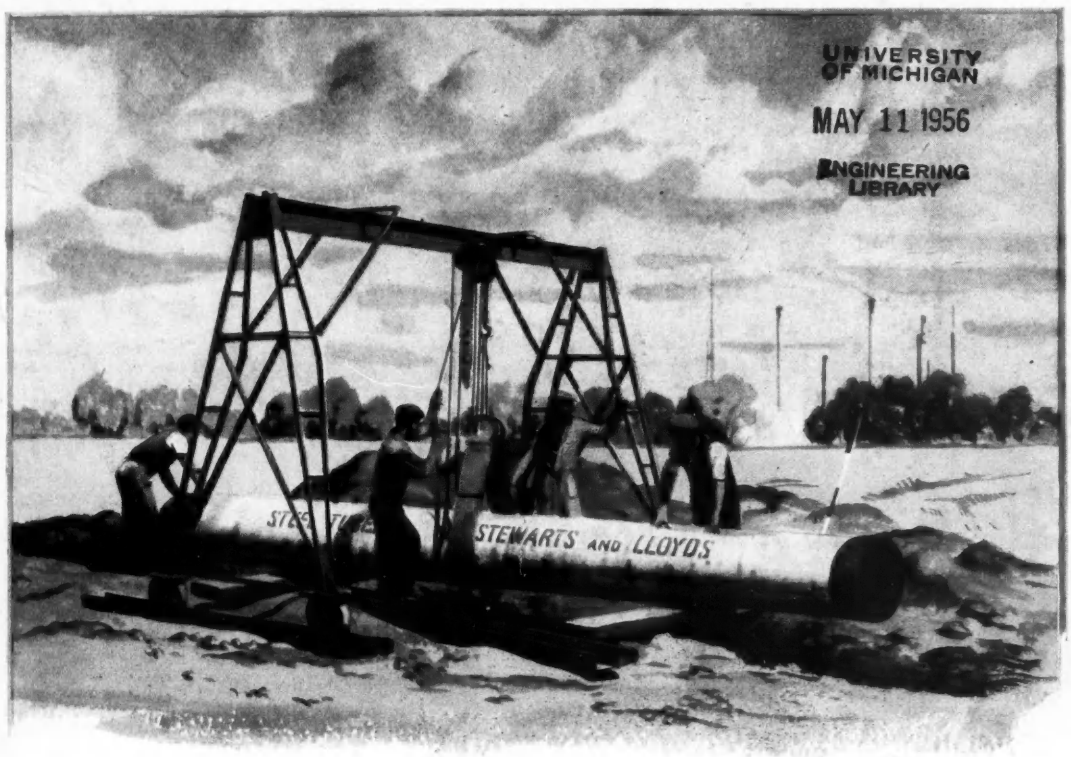
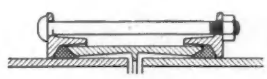
The Engineer

APRIL 20, 1956 28 ESSEX ST., STRAND, LONDON, W.C.2 TWO SHILLINGS



THE STEEL TUBE AGE

Part of a 24-inch S & L steel water main, about 22 miles long, being laid by the West Hampshire Water Company from their works on the River Avon at Christchurch, to provide the water supply to the Esso Refinery at Fawley, Southampton.



The pipes, joined by Viking Johnson couplings (see section above), are sheathed externally and lined with bitumen.

STEWARTS AND LLOYDS LIMITED

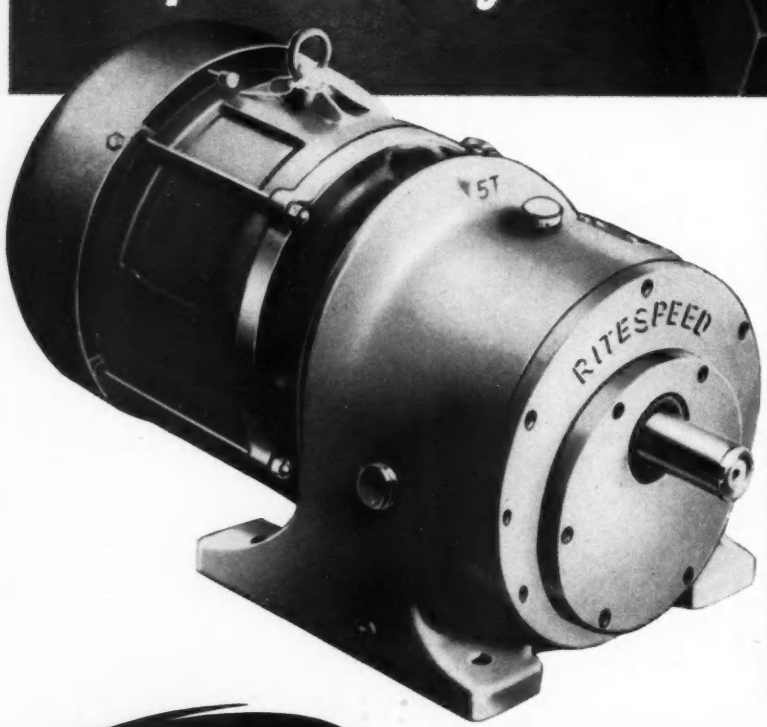
GLASGOW • BIRMINGHAM · LONDON

S&L

9 Good reasons why...

Crofts RITESPEED

is the drive for productivity!



★ An entirely new development in design embodying a Cartridge Assembly housing the gear train.

★ Unique Cartridge Assembly facilitates interchangeability of High Speed Wheels and Pinions of different ratios providing a wide range of output speeds.

★ Wheels and Pinions to meet all speed requirements are available from STOCK.

★ Adaptable to any make and type of electric motor.

★ Horizontal, Wall or Ceiling Mounting.

★ Positive lubrication system.

★ Compact, robust and of modern appearance.

★ Powers range from Fractional up to 20 H.P. for "Ritespeed" Cartridge Units. Larger Units without cartridge assembly up to 80 H.P. Speed ratios up to 82 to 1.

★ IMMEDIATE DELIVERY FROM STOCK UP TO 20 H.P.

Write for Publication No. 5329/5330/10

Crofts (ENGINEERS) LIMITED BRADFORD 3 ENGLAND

PHONE — 65251 (15 LINES) GRAMS — "CROFTERS BRADFORD"

THE ENGINEER

VOL. 201 No. 5230 APRIL 20, 1956

CONTENTS

LEADING ARTICLES—
Savings, not Taxation 357
Maintenance of Road Transport Engines 358

ARTICLES—
"Auris" Gas Turbine. (Illus.) 383
Barium Titanate Accelerometers and Strain Gauges. (Illus.)... 382
British Industries Fair. No. I. (Illus.) 360
Engineering and Scientific Applications of Digital Computers 372
Engravings of 1866... 374
High-Speed Five-Stand Tandem Cold Strip Mill. No. II. (Illus.) 378
Institute of Metals... 359
Institution of Naval Architects. No. III 376
Materials for Nuclear Power Engineering 369
Modernisation Plans for British Railways 383
Mr. Ernest Brook 359
North of Scotland Hydro-Electric Schemes. No. VII, Part I. (Illus.) 364
Railway Electrification Programmes from Liverpool Street and Fenchurch Street 359
Report on Proposed Firth of Forth Road Crossing 381
Speed Limit in the London Traffic Area 359
Training for Automation 359
Underground Gasification Trials in Great Britain. No. II. (Illus.) ... 379
Work Study Advisory Service for the British Transport Commission ... 359
100 Years Ago... 358

AMERICAN SECTION—
Work of the U.S. Atomic Energy Commission. No. I. (Illus.) 387
Commercial Atomic Power Equipment Department of General Electric ... 389

LETTERS AND LITERATURE 375

LETTERS TO THE EDITOR—
"The Model Technique" (Illus.) 375
Boys and Careers 375

LITERATURE 375

NEWS AND NOTES—
British Patent Specifications. (Illus.)... 391
British Standards Institution... 383
Catalogues and Brochures 392
Continental Engineering News. (Illus.) 385
Forthcoming Engagements 392
Industrial and Labour Notes 384
Launches and Trial Trips 392
Personal and Business 390

SAVINGS, NOT TAXATION

It is for us a very unfortunate fact that owing to some peculiar custom of Parliament a Chancellor, in presenting a Budget, invariably does so on a Tuesday afternoon. Full reports of his speech are therefore not available to us before Wednesday morning, the very day on which we go to press. Thus we are, in commenting upon a Budget, in much the same embarrassed state as the Opposition speaker in the House who is expected to get upon his feet and criticise as soon as the Chancellor sits down! There is little time for reflection. Yet everyone, we suppose, has in some sense, as Budget day approaches, attempted according to his own view of the economic situation, to assess what changes it would be practicable for the Chancellor to make and which amongst them is the more desirable. On this occasion the Chancellor must have realised many expectations. The credit squeeze, which has been progressively tightened ever since last summer, has been criticised because, though it has affected consumption in some degree, it has more effectively restricted investment in capital assets. But the rate of investment in such capital assets is already, by comparison with other countries' performance, too low. A more direct attack upon consumption, it has been held—by ourselves amongst others—would not only stimulate exports, but leave room, too, for more investment. The Chancellor has chosen to make that attack not through increased taxation—a method that he characterised as paying out far more money to the people than it is good for them to have and then taking it all from them again by taxation—but by increasing the incentive to save. The emphasis of this Budget, in fact, is upon saving, and even the Government itself is to be drawn in, since the Chancellor hopes to reduce governmental expenditure by some £100 million per year. Besides new Premium Bonds, there are to be more attractive Savings Certificates and more attractive Defence Bonds. Even certain reliefs of taxation granted, for example, to the self-employed, are intended to stimulate savings.

But, unfortunately, the Chancellor has not restricted himself to the stimulation of savings. A mild check, too, is imposed upon capital investment. The intention, for example, that for two years the nationalised industries shall borrow on capital account directly from the Government seems to indicate a desire for more control and, no doubt, some restriction of the rate of their capital expenditure; and, again, the increase in the tax on undistributed profits must operate to slacken the rate of industrial investment. Nor, curiously enough, does the increase of tax on distributed profits really accord with the Chancellor's desire to encourage savings. Thus, though the emphasis of the Budget is upon savings, its main intention is to provide a further corrective to an economic situation believed to be still inflationary. Yet, for our part, we cannot help asking whether further restrictive measures are really necessary. For the oversea trade returns for February and March suggest that in reality the economic emergency is over and that at long last the credit squeeze has done its work. If so, the time may well have come when the screw, instead of being further tightened, ought to be slacked back. But unfortunately economists have to act—as the Chancellor pointed out—on information that takes so long to collect that it has little relevance to the present. It is as though the governor of a steam turbine reacted not to existing conditions, but to those ruling five minutes before! Even if load changes were in fact small, violent hunting would be the consequence. The relevance of such an analogy was not lost on the Chancellor. But he remarked "a misjudgment on the side of over-optimism might have the gravest results . . . an error in the opposite direction would be far less harmful." No doubt he is right. Yet we cannot agree that if the squeeze is seen to be going too far it is simple to correct it. Just as the squeeze takes time to develop its consequences, so does it take time before its relaxation can become effective. Too great severity now may well produce a swing towards a real deflation. Yet would that consequence be altogether bad? For certainly it would be delightful if at some time in the future the Chancellor's dream came true and, as he expressed it, "a joint deputation from the F.B.I. and the T.U.C. comes to see me asking for the abolition of surtax and profits tax and the immediate reduction of all indirect taxation."

MAINTENANCE OF ROAD TRANSPORT ENGINES

Most appropriate, for these days, was the theme of the paper read before the Diesel Engineers and Users Association on March 15th by Mr. A. T. Wilford, director of research, London Transport Executive. While dealing primarily with smoke emission from road transport engines, the contents of the paper are of value to users of oil engines in other categories and Mr. Wilford has performed a valuable service by exposing the causes of objectionable exhaust smoke and describing the action which must be taken if this kind of nuisance is to be suppressed. "Emission of objectionable

exhaust smoke can be avoided (writes the author), firstly, by ensuring that the engine maker's recommended setting for the fuel-injection pump is not exceeded, and, secondly, by adopting a proper system of inspection and maintenance of the engine and fuel-injection equipment." Mr. Wilford emphasises, however, that a setting which gives the rated power output, together with exhaust products, " virtually free from carbon monoxide with little more than a haze of smoke," must leave small margin for " variations which can occur during the period between inspections." It is for this reason—as the author states—that the majority of operators of public service vehicles, including London Transport, prefer to employ " a setting which is lower than that recommended and has the effect of derating the engines by about 10 per cent." This procedure is, of course, the result of massive experience in the operation of public transport vehicles, and after illustrating the adverse effect of over-injection, Mr. Wilford points out that apart altogether from consideration of the exhaust products, " if increased power is required it is much more economical to use an engine of larger capacity. Not only will fuel consumption be reduced, but because the engine is being operated within its designed capacity, there will be a substantial increase in life between overhauls." The Air Pollution Committee's Final Report (November, 1954) has emphasised the vital need for such engine research as will enable smokeless operation to be achieved, but even with the best possible engine smokeless operation must be dependent on a number of factors, the nature of which forms the main subject of Mr. Wilford's paper. He emphasises, for example, that " a properly chosen setting for the fuel-injection pump, whilst initially effective in preventing exhaust smoke, will not continue to do so without the adoption of a system of planned maintenance covering not only the fuel-injection pump, but also the injectors, and, of course, the engine as a unit. Nor can the fuel or the engine lubricating oil be neglected. But all these precautions will fail if fuel-injection pump settings are deliberately interfered with by drivers or by garage maintenance staff."

In addition to showing the influence of systematic maintenance of injection equipment upon combustion efficiency, Mr. Wilford has described in detail the inspection and maintenance practices used within London Transport. That the procedure adopted is successful receives powerful confirmation from the fact that " at the present time a London Transport bus runs on an average 58,000 miles before encountering an involuntary stop due to engineering causes, an involuntary stop being defined as any delay exceeding five minutes' duration." Significant of maintenance technique evolved as the result of many years of experience is the procedure whereby the garages are not responsible for maintenance work of a major character : " Where the amount of work required is beyond the scope of garage maintenance schedules, the unit is removed and replaced by a newly overhauled counterpart already available in the garage stores." Extremely interesting and informative are the details given of the routine tests made in order to render it as certain as possible that the main elements of the equipment (engines, gearboxes, rear-axle assemblies, road spring assemblies, fuel-injection pumps, injectors, dynamos, batteries, &c.) shall remain in satisfactory condition for prolonged periods of operation. We note that in London Transport buses the engine crankcases are " drained and refilled with fresh oil at intervals of nine weeks, corresponding to approximately 7500 miles' running in service," the oil in use throughout the fleet being of the low viscosity detergent type. A further and most interesting section of the paper relates to the procedure in maintaining injectors, it being recognised that unless the injectors are kept in good condition, after being correctly assembled at the outset, there must be excessive emission of exhaust smoke. Within London Transport injectors are at present removed for cleaning and testing by experienced garage staff at intervals corresponding to 15,000 miles' running in the Central area. There are, moreover, investigations now in hand which may result in lengthening the intervals between injector inspections. On the important matter of the content of carbon monoxide in the exhaust gases from diesel engines, Mr. Wilford confirms that where there is an acceptable standard of freedom from smoke, the exhaust gases from such engines are unlikely to contain more than 0·2 per cent of carbon monoxide. In this connection, it is to be noted that tests made by the Stanford Research Institute (" The Smog Problem in Los Angeles County ") are reported as having shown how the average petrol engine discharges about 7 per cent of its fuel intake in the form of unburnt hydrocarbons. On the other hand, a diesel engine with exhaust smoke at the maximum permissible level—defined as a level at which there will be no public complaint—discharges only 2 per cent of its fuel unburnt.

Reference was made during the discussion on Mr. Wilford's paper to the extensive use, in underground mines, of diesel locomotives. With mining locomotives, however, where 0·2 per cent of carbon monoxide is the maximum permitted amount, the volume of ventilating air is such as to render entirely negligible the actual percentage of carbon monoxide in the atmosphere underground. Mr. Wilford's description of the precautions taken by London Transport with a view to keeping down the percentage of carbon monoxide in the exhaust from their engines reveals how it has been possible to maintain the combustion efficiency at such a level that with a bus engine in normal mechanical condition " it is quite usual for carbon monoxide to be returned as 'nil,' meaning less than 0·2 per cent. . . . Analyses of samples from a random selection of buses have yielded figures ranging from 0·01–0·15 per cent of carbon monoxide." The information given in this paper comes to us at a time when a substantial fraction of the traffic (both passenger and freight) formerly carried on the railways is now filling the highways, and some of it, indeed, is airborne. Mr. Wilford performs a public service not only by naming the various causes which produce contamination of the air at street level, but by describing procedures which have been found effectual in removing them.

100 Years Ago

The Engineer

(APRIL 18, 1856)

" STEAM COMMUNICATION WITH AUSTRALIA "

" A large and influential public meeting, convened at the instance of the General Association for the Australian Colonies, was held on Monday, at the London Tavern, Bishopsgate-street, to determine on the best means to be taken to insure the immediate re-establishment of our steam postal relations with Australia. The Right Hon. the Lord Mayor was called to the chair.

" Mr. Wentworth moved a resolution to the effect that while the long-continued interruption of all postal steam intercourse with the Australian colonies had been productive of serious discontent and detriment to them, it had been in a still greater degree injurious to the commerce and finances of the United Kingdom. The Earl of Hardwicke moved that it was expedient that immediate steps be taken to establish a steam postal service suitable to the vast commerce and growing importance of Australia. Lord Stanley moved a resolution to the effect that it appeared that, provided the usual postal speed of 10 knots could be attained, the transit of letters between London and Melbourne might be easily effected in forty-four days.

" Mr. E. Stevens said he had just come to this country from Australia, and was well acquainted with the feelings of the colonists on this question. He wished to say that he did not believe it possible to get to Australia in forty-four days, nor did the colonists themselves desire to see such a consummation. They had but one simple request to make in this matter, and that was to have no more experiments in reference to it (cheers). They were sick of delay and sick of change ; they had plenty of money to pay for steam postal communication ; and they asked the Imperial Government to concede it to them at once. On the question of route he contended that Diego Garcia was a *terra incognita* to the British sailor, and that they would lose one ship out of four if they sent them by that route (hear, hear).

" On the motion of Mr. R. W. Crawford, petitions signed by the chairman, and founded on the resolutions, were agreed to be presented to both Houses of Parliament."

A Seven Day Journal

Railway Electrification Programmes from Liverpool Street and Fenchurch Street

EARLIER this week British Railways, Eastern Region, gave an outline of electrification plans for the next five years, involving lines running eastwards from Liverpool Street and Fenchurch Street, which will form part of the scheme for electrification at 25kV and 50 c/s. The existing Liverpool Street–Shenfield services work on the 1500V, d.c. system and the two immediate extensions to this line will also start operation on the same system : the line from Shenfield to Chelmsford will open for electric traction on June 11th of this year and that from Shenfield to Southend (Victoria) about December 31st this year. New mileage being electrified comprises about 9½ miles from Shenfield to Chelmsford and 21¼ miles from Shenfield to Southend (Victoria). It is hoped to convert the Liverpool Street, Chelmsford and Southend (Victoria) lines to the new a.c. system during 1959. Under bridges and in tunnels the 1500V d.c. clearances are sufficient for a.c. at 6·6kV and power will therefore be supplied at this voltage where it proves too expensive, or impracticable to give the greater clearances needed for 25kV. The transition from one voltage to the other will be made without affecting the running of the train. The current will be transformed and rectified through equipment on the vehicle and the existing d.c. motors will continue in use. The lines from Colchester to Clacton and Walton will be used as a proving ground for new equipment and vehicles on the 25kV system. The Fenchurch Street line will be electrified on the new standard system, 6·6kV in the inner zone and 25kV in the outer zone. The provisional time table for the whole programme is : June, 1956, electrification to Chelmsford ; December, 1956, electrification to Southend (Victoria) ; Spring, 1958, electrification of Colchester, Clacton and Walton branches on the a.c. system ; Spring, 1958/1959, testing of new multiple-unit trains and operation in the Colchester, Clacton and Walton local services ; 1959, conversion of the Liverpool Street, Chelmsford and Southend (Victoria) lines to the a.c. system ; 1960, electrification of the Enfield Town, Chingford, Hertford East and Bishop's Stortford lines; and, 1961, electrification of the London, Tilbury and Southend lines.

Institute of Metals

THE spring meeting of the Institute of Metals was held in London last week. It began on Tuesday evening, April 10th, when Dr. Willis Jackson, F.R.S., delivered the May lecture entitled " Ferroelectrics : the Dielectric Analogue of Ferromagnetics." On the following morning there was the annual general meeting of the Institute, when the total membership was stated to be 4578. At the conclusion of the formal business, Major C. J. P. Ball was inducted to the presidential chair and delivered his address. The sessions for the discussion of papers were on Wednesday afternoon, Thursday and Friday. Three papers on " Materials for Nuclear Power Engineering " were presented on Wednesday afternoon, and a report of the discussion on them appears on page 369 of this issue. At the subsequent sessions there were discussions on the final forming and shaping of wrought non-ferrous metals ; powder metallurgy ; embrittlement and fracture ; rolling textures and recrystallisation, and alloy thermodynamics. The Institute's dinner and dance were held at Grosvenor House on Wednesday evening, April 11th. The four speeches made were all brief, enjoyable and suitable to the occasion, but they require little notice here. Lord Reading, for example, in proposing the toast of the Institute of Metals and Non-Ferrous Metal Industries, became delightfully confused between those well-known herbaceous flowers Zirconium, Beryllium, Sodium and Lithium and the less-known metals, Alyssum, Antirrhinum and Geum ! Other speakers were Major C. J. P. Ball, president of the Institute, who replied to Lord Reading, Mr. John Grimston, who proposed the toast of the Guests, and the Lord Bishop of Chester, who replied for them.

Speed Limit in the London Traffic Area

THE Ministry of Transport and Civil Aviation has published the report of a sub-committee of the London and Home Counties Traffic Advisory Committee, which was appointed in November, 1954, to review the 30 m.p.h. built-up area speed limit. The sub-committee's terms of reference also directed that it should examine the case for introducing differential speed limits on main traffic routes in the London traffic area, whether or not at present restricted. One of the principal conclusions reached by the sub-committee is that the general speed limit of 30 m.p.h. in built-up areas has helped to keep down the number and severity of accidents in the London traffic area and should continue in force. The sub-committee says that " neither on safety nor traffic grounds is there a case for altering the present rate of 30 m.p.h. for this speed limit." It adds that it would be undesirable to suspend the general speed limit in the early hours of the morning. A majority of the sub-committee recommends the introduction of a differential speed limit on certain lengths of road on the main traffic routes where a 30 m.p.h. speed limit is unnecessarily restrictive. But it is suggested that only one differential speed limit should be adopted, and that should be 40 m.p.h. Where adopted, it is added, the differential speed limit should apply for twenty-four hours a day. The report records that a minority of the sub-committee is opposed to the introduction of a differential speed limit, but, in view of the conflict of opinion and of the lack of data, considers that an experiment with a speed limit of 45 m.p.h. on a few sections of road might enable a more factual assessment to be made.

Work Study Advisory Service for the British Transport Commission

A SPECIALIST advisory service in work study is to be established by the British Transport Commission to develop the schemes for increased efficiency and planned productivity. The setting up of this service follows an agreement by the British Railways' Productivity Council that planned productivity through work study can play an important part in increasing efficiency on British Railways. Mr. E. J. Larkin, assistant mechanical and electrical engineer of the London Midland Region, has been appointed director of work study at the Commission's headquarters, and he will take up his new duties on May 1st. His main responsibilities will be the provision of the specialist work study service and organising a work study training centre. These facilities will be used in the development of work study in relation to all activities of the Commission. The staff college at The Grove, Watford, will be used for work study training, and a principal for this purpose will shortly be appointed. A small advisory committee, on which representatives of industry and trade unions will be invited to serve, will be set up to assist the director of work study and the principal of training.

Training for Automation

A CONFERENCE under the general title " Management Looks Ahead " was held at Southport last week-end. It was organised by the British Institute of Management, and at one of the sessions a paper on " Making Automation a Reality : the Role of Training and Education," was presented by Mr. C. L. Old, principal of the Wolverhampton and Staffordshire Technical College. Mr. Old suggested that it was unwise to think of training people specifically for automation since it was very unlikely that automation would ever be applied to more than a portion of industry. The basic industries such as mining, metal extraction and agriculture, he said, still needed much more mechanisation and electrification. Transport and distribution would have to expand, and vastly greater power would be needed from generating stations. All these things were going to call for more and more technically trained manpower at all levels of skill and knowledge. The only hope, Mr. Old urged, was to regard people as our most valuable raw material ; in other words, to train every man and, indeed, every woman, to his or her highest potential. Mr. Old went on to say that the technical preparation for automatic factories could not be considered in isolation, but only as part of a developing industrial scene. This meant more and better technically trained manpower at all levels and the continuing exploitation of ideas and " know-how." More and better technical education, Mr. Old commented, implied a better grounding lower down in the educational system.

Mr. Ernest Brook

WE have learned with regret of the death, at his home in Huddersfield, last Monday, April 16th, of Mr. Ernest Brook, the founder and past chairman of Brook Motors, Ltd. Mr. Brook, who was eighty-two, was born at Pontefract, and was educated at the Leeds School of Science and Art. In the early part of his electrical engineering career, he spent some years on the staff of Greenwood and Batley, Ltd. At the beginning of the present century, however, Mr. Brook decided that the future of the electric motor was a particularly promising one, and in 1904 he went into business on his own account, occupying one room in Huddersfield and employing a staff of two. The firm which has grown up from that small beginning now employs well over 2000. In addition to its works at Huddersfield, it opened another factory, a few years ago, at Barnsley for the production of electric motor stators. Mr. Brook was the chairman of the company until 1951, and since then has continued to serve on the board. He was an associate member of the Institution of Electrical Engineers, honorary vice-chairman of the Huddersfield Engineers' Training Association, and a governor of the Huddersfield Technical College.

British Industries Fair

No. I

THE British Industries Fair opens on Monday next at Olympia, London, and Castle Bromwich, Birmingham, and it will be open daily until Friday, May 4th. As in previous years, the engineering exhibits will be mainly concentrated at Castle Bromwich, although there will be sections for electrical and electronic industrial equipment and scientific and optical instruments at the Olympia. Preliminary information received from exhibitors indicates that, although a certain amount of engineering equipment of new design is to be shown, a great deal of it has been displayed at previous exhibitions or has already been described in our columns.

An innovation this year will be a display, arranged by the organisers in co-operation with the Department of Scientific and Industrial Research, of new products and processes developed by the application of results of research. The products and processes to be shown have been chosen from some 250 submitted by industrial firms, and they cover a wide field, ranging from metallurgy to paint milling, pumps to pill coating machines and a boot sewing machine to road lamps.

In the following article, particulars are given of some of the equipment of new design or incorporating recent improvements.

Scottish Machine Tool Corporation, Ltd.

The heavy equipment to be exhibited on the stand of the Scottish Machine Tool Corporation, Ltd., includes a 300-ton press with a 10in stroke and a 100-ton press of the firm's Craig and Donald Press Division. This 100-ton press has a width of 16½in between its sides and a fixed stroke of 8in. The slide has a height adjustment of 1in and when it is right up the vertical die space available is 17½in. A 10 h.p. squirrel-cage motor drives the machine through single gearing and with the clutch continuously engaged the press will give forty-five working strokes a minute. Three push buttons control the machine through a solenoid-operated air valve and a heavy-duty air-operated clutch and brake. Automatic stopping is provided at the top stroke position by an adjustable cam and an electrical limit switch.

The same firm is also showing a universal folding and bending machine similar to that in Fig. 1, but with the gearbox at the left-hand side of the machine. It is designed to fold or bend mild steel plate up to 8ft long and ¼in thick, and has a swing-out top beam. With this swing-out top clamping beam, enclosed shapes can be quickly and easily withdrawn from the machine. The beam is carried on large-diameter steel supports and is adjustable through screws and enclosed worm gearing. The folding beam swings in two trunnion bearings on the end standards of the machine, and is driven through quadrants at each end by gearing. The machine is driven by vee belts from the main motor through two sets of heavy-duty reversible clutches and gearing, and a safety clutch is provided on the clamping gear to prevent the top beam from being too tightly closed.

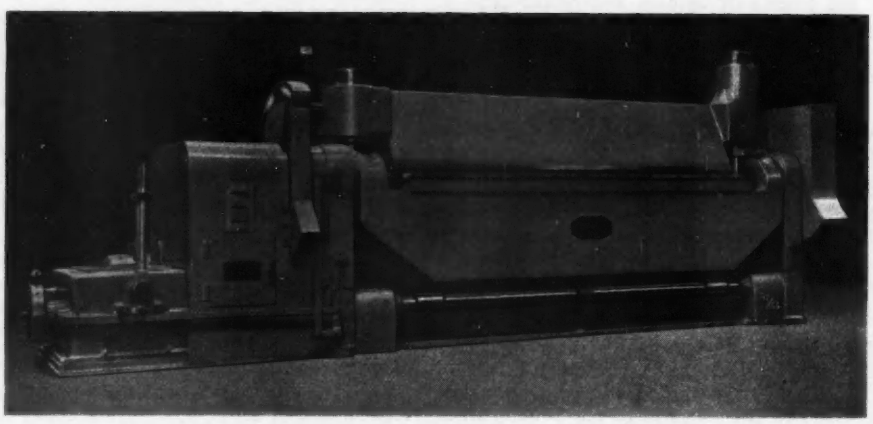


Fig. 1—Universal folding and bending machine, with swing-out top beam, for mild steel plates up to 8ft long and ¼in thick—Scottish Machine Tool Corporation, Ltd.

Bronx Engineering Company, Ltd.

A 60-ton press brake of all-steel welded construction to be shown by the Bronx Engineering Company, Ltd., Lye, Worcs (Fig. 2), has a capacity of 8ft long, 10-gauge mild steel between the columns and 10ft long, 12-gauge mild steel overall the beams. It makes thirty strokes a minute, the stroke length being 3in and the die space with the stroke down and adjustment up is 11in.

The bottom beam of this press rests on machined abutments on the two wide columns, and it is welded in position to form with the heavy top crown a rigid box structure. All pressure from the top beam is transmitted direct on to the centre line of the two main columns.

Top beam adjustment is by a separate 2 h.p. flange-mounted motor driving a train of reduction gears to a steel worm and phosphor-bronze worm wheel nut on each connecting-rod. A dog clutch is provided so that the top beam can be positioned parallel to the bottom beam, and limit switches are fitted to prevent overrun of the beam either up or down. The connecting-rods are of cast iron fitted with large-diameter phosphor-bronze bush bearings for the eccentric shaft throws. Spherical ended ball screws of high-tensile steel work in the large solid phosphor-bronze worm wheel nuts for raising and lowering of the top beam. The ball screws are located by square-ended pins in cast steel pressure cups which are designed to give full bearing seating. The eccentric shaft forged from 0·50 per cent carbon steel is machined and ground all over except on the sides of the eccentric throws.

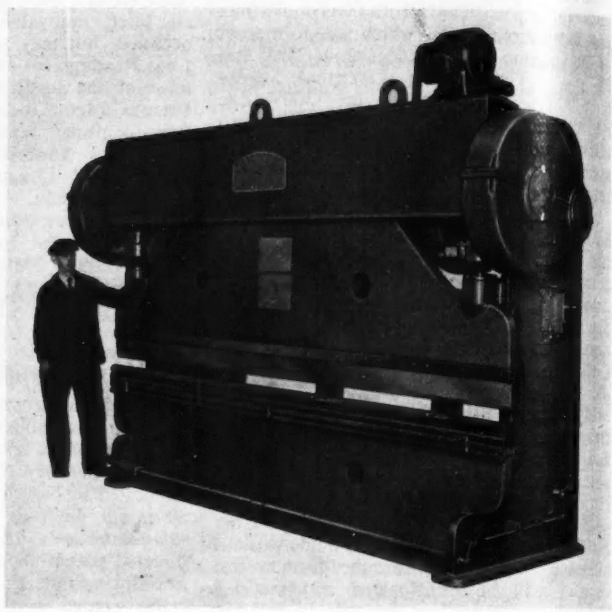


Fig. 2—60-ton press brake with a capacity of 8ft long 10 gauge mild steel between the columns—Bronx

Drive is from a 6 h.p. high-torque motor through vee belts to a flywheel running on ball and roller bearings on the first motion shaft. A multi-plate friction clutch bolted to a register on the flywheel operates in conjunction with a brake so that inching of the top beam can be carried out under full control by the machine operator.

John Mills (Llanidloes), Ltd.

Amongst the " Oilaulic " hydraulic presses on the stand of John Mills and Co. (Llanidloes), Ltd., will be the 6-ton bench machine, illustrated in Fig. 3, which is fitted with an indexing table. This table can be used as an indexing unit, or arranged as a rotary conveyor with the working surface increased from the standard 24in diameter by the superimposing of a top plate of the required size. It can also be arranged as a continuous running transfer unit or as a rotating assembly table.

To ensure easy rotation of the table the contact surfaces are separated by a spring resting on a ball which, except when working loads are applied, acts as a thrust bearing to take the weight of table and tooling with very little friction. When the table is under load the spring yields, allowing the table to rest on the cast iron housing.

The table is a solid disc 2¾in thick with an integral central stem working in bearings

in the cast iron housing. A gear ring shrunk on the underside of the table is driven by a hydraulic motor through a pinion carried in ball and roller bearings. Sunk in accurately spaced recesses under the table are taper ground sockets for the index plunger, which works in a steel sleeve mounted in the housing. The plunger is engaged by a spring and withdrawn by a hydraulic ram which also functions as a piston valve, admitting oil to the motor only when the index plunger is fully disengaged.

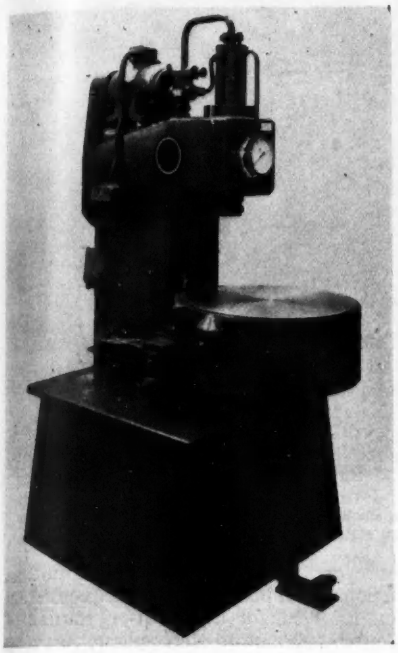


Fig. 3—6-ton hydraulic bench press fitted with 24in diameter indexing table operated through the hydraulic system of the press—Mills

In the standing or locked position, the oil supply is by-passed via the main piston valve, held down against spring load by a catch, and a by-pass valve, held up by a spring. When the catch on the main valve is tripped the spring lifts the valve, admitting oil to withdraw the index plunger and then to drive the motor, and to depress the by-pass valve, the function of which is described below.

Corresponding to each station on the table there is a cam on the periphery so placed that as the index point is approached the cam acts on a roller on the main valve, depressing it so that the catch engages. In this position oil is released from the index withdraw ram, allowing the index plunger to bear on the underside of the table. At the same time, the motor exhaust is made to pass through an adjustable orifice, checking the speed of the table, so that when the index point is reached, engagement takes place without shock.

Following up the plunger as it engages the withdraw ram valve releases pressure from the by-pass valve, exhausting the whole circuit. Until that stage pressure is maintained on the motor by the by-pass valve, thus ensuring positive action in spite of the retardation.

When fitted on a hydraulic press the pressure supply to operate the table can usually be taken from the pump powering the press. On other applications a small motor pump unit is connected by flexible pipes to the table.

Rubery Owen and Co., Ltd.

The foundry plant exhibited will include an interesting model of the "Hallsworth" automatic moulding system to be shown on the stand of Rubery Owen and Co., Ltd., of Darlaston, S. Staffs. The plant is primarily intended for the production of small repetitive castings, and it includes every piece of equipment necessary to lay out a completely mechanised foundry using vertically poured boxes of 12in by 9in by 5in. The basis of the plant is the four-station, self-indexing moulding machine performing the operations of sand metering, edge tucking, squeezing, removal of surplus sand, mould pattern stripping and mould "take-off." Closing of moulds, together with any necessary coring, is carried out by hand on a conveyor track, and the complete mould is loaded into a rotary mould conveyor unit which automatically clamps and tilts the mould and then delivers it to the pouring station at the correct angle for casting.

The mould is shaken out on a vibrating grid and used sand is returned underground to a sand conditioning unit, where it is automatically reconditioned in a sequence controlled order before redelivery to the moulding machine.

The plant uses a relatively small size of box, which facilitates automatic handling, reduces operator fatigue and increases the output when combined with vertical pouring.

The system is stated to be particularly flexible, and it can be installed in foundries possessing some equipment which could be substituted for part of the system.

A photograph reproduced in Fig. 4, shows the station where the closed moulds are made to slide down a ramp on to the pallets of the pouring conveyor. The pallets tilt the moulds before they reach the pouring station at the rear.

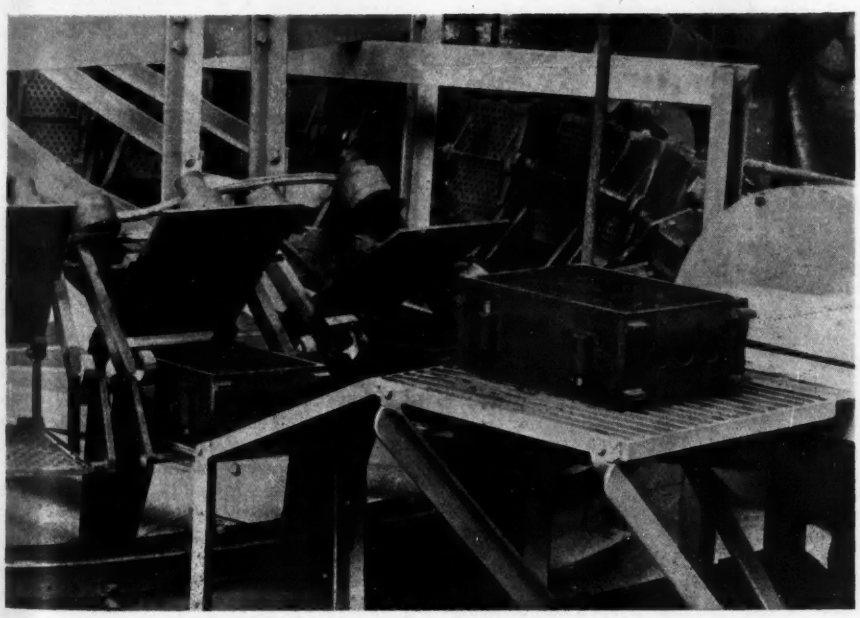


Fig. 4—Mould loading station of "Hallsworth" automatic moulding system for small repetitive castings. The pallets tilt the moulds as they are carried to the pouring station at the rear—Rubery Owen

Turner Brothers (Birmingham), Ltd.

Turner Brothers (Birmingham), Ltd., Cleveland Street, Birmingham, will show one of a batch of four 100-ton geared power presses it has developed for use with special tooling made by the firm. It takes tooling up to 36in left to right by 13in front to back by 23in shut height. The ram moves on four precision ground pillars which guide as close as possible to the tool and ensures accuracy of ram travel throughout its 8in stroke and 9in adjustment. This press has an air cushion enclosed in the ram which operates a top pressure pad in the tooling. A positive bottom knock-out is driven directly from the crankshaft so as to eject the component during the upstroke of the press for mechanical or air unloading, and to return the ejector pad leaving the die clear for component location as the press stops at the top of the stroke. The reciprocating weight of the ram and tooling are fully balanced by air cylinders, and the action of the connecting-rod is taken through a large section plunger which is separately guided so that tilting forces cannot be transmitted to the ram.

Solid steel side members, 3in thick, which are completely free from welding on stress points, form the basis of a rigid structure for the press frame. The drive from a 10 h.p., high-torque motor is transmitted to the flywheel through a variable-speed drive, and the clutch is of radial sliding key design operated by a treadle through a single stroke mechanism. The speed of the press can be varied between twenty-five and fifty strokes per minute.

This firm will also exhibit a group of bending machines for the production of washing machine cabinets and cases, and representative examples of the pressings, plastic impressions and die castings made with tools it manufactures to special requirements.

Some of the exhibits to be seen in the electrical section at Olympia are described and illustrated below.

A. Reyrolle and Co., Ltd.

Extra-high-voltage switchgear will be prominent among the exhibits shown at Olympia by A. Reyrolle and Co., Ltd., Hebburn, Co. Durham. Examples of both air-blast and small-oil-volume circuits will be included in the display.

The main exhibit will be a single-phase unit of a 300kV, 2500MVA air-blast circuit breaker, complete with its local air receiver. A typical complete installation of this class of switchgear (at a C.E.A. power station in the Midlands) is illustrated in Fig. 5. The single-phase unit as exhibited consists of six air-blast "turbulators" connected in series with an "isomaker," which provides the necessary clearance across the circuit breaker in the open position and is capable

of making its rated making current. The circuit-breaking heads containing the " turbulators " are mounted in pairs on three porcelain columns, and the " isomaker " moving arm and its other fixed contact (one of its fixed contacts being integral with the terminal of one of the heads) are supported on similar

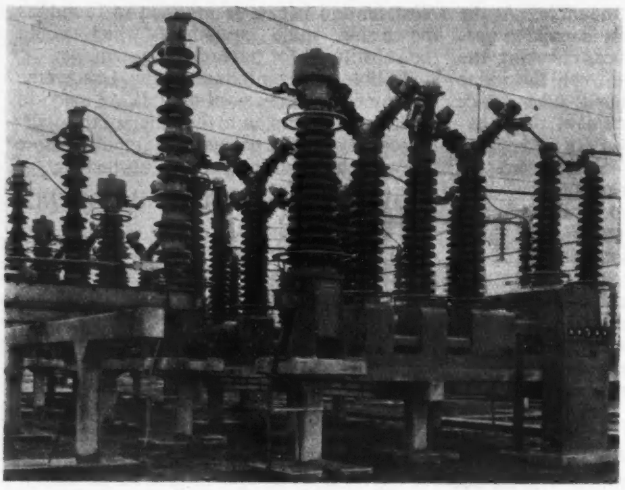


Fig. 5—275kV, 7500MVA air-blast circuit breaker installed at a C.E.A. power station in the Midlands—Reyrolle

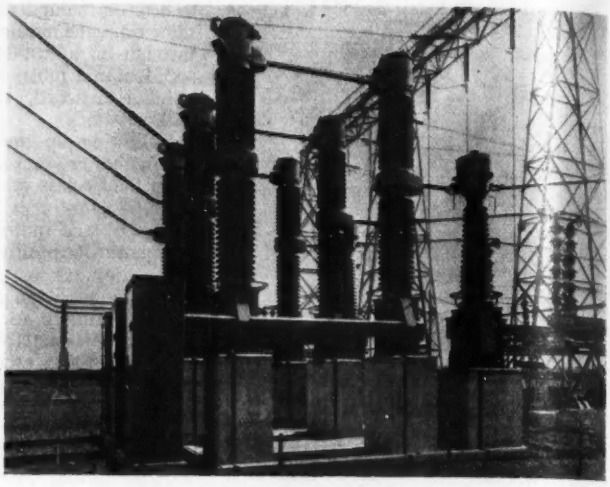


Fig. 6—220kV, 5000MVA small-oil-volume circuit breaker at Thomastown terminal station, Australia—Reyrolle

porcelains. On opening, the arcs are extinguished in the six " turbulator " heads and immediately after clearance the " isomaker " is opened. The moving contacts in the " turbulator " heads then return to their closed position in readiness for the next closing operation of the circuit breaker which is done by means of the " isomaker." A sectioned " turbulator " head will be included in the display to show the action of the moving contacts and to indicate the principle of arc extinction. Alongside the circuit breaker will be two 300kV post type current transformers, one of which is complete, while the other is displayed without its porcelain insulator and casing to show the internal construction of the primary and core. The main insulation consists of oil-impregnated paper, the whole of the housing being filled with oil, and special precautions are taken to ensure that the paper is kept free from moisture.

The second e.h.v. circuit breaker shown is a completely sectioned single-phase unit of a 132kV, 2500MVA, small-oil-volume circuit breaker. This consists of three portions, namely, a supporting compartment, a circuit-breaking compartment, and a metal top cap with a gas vent. The supporting compartment includes an oil-filled metal base chamber and a porcelain insulator, within which the operating links for the moving contact are contained. The circuit-breaking compartment includes upper and lower fixed contacts ; through the latter the moving contact stem slides, and all these items are contained in a cylindrical bakelised paper tank, surrounded in turn by a porcelain insulator. The oil in the bakelised paper tank, used as the arc-extinguishing medium, is entirely separate from the insulating oil, which fills the supporting compartment below and the annular space between the tank wall and the upper porcelain shroud. The metal top cap, from which the upper fixed contact, with its " turbulator " arc control device is suspended, is fitted with a silica-gel breather and oil level indicators.

A typical installation of this class of switchgear is at Thomastown terminal station, as illustrated in Fig. 6.

Metropolitan-Vickers Electrical Company, Ltd.

The actuating mechanism for combined control and shut-off rods of a thermal nuclear reactor will be shown at Olympia by Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester, 17. The mechanism is designed to provide a slow " out " and two faster " in " speeds, and to hold the rod in any required position. It is also capable of giving a controlled shut-off of the reactor independently of the electrical supply. It consists of a synchronous-control torque motor, fed from a variable-frequency supply, driving through a 20 : 1 reduction gear on to a cable reel. The speed of the rods to the shut-off condition is controlled by a permanent-magnet, eddy-current brake. Indication of rod position is given by a geared magslip transmitter. The whole mechanism is dry lubricated by molybdenum disulphide ; 120 of these mechanisms (Fig. 7) are being supplied by the company for the Calder " A " power station of the United Kingdom Atomic Energy Authority.

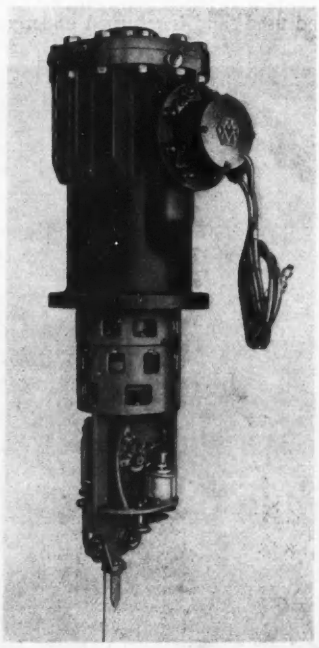


Fig. 7—Actuating mechanism for combined control and shut-off rods of a thermal nuclear reactor—Metropolitan-Vickers

A recent addition to the company's " MU " range of flameproof mining equipment will also be shown : it is the " MCU82 " contactor unit for squirrel-cage motors driving coalcutters, loaders and conveyors. It has been designed to the National Coal Board's Standard Specification No. P.3/1950, for the direct-on starting of squirrel-cage motors—three-phase, 50 c/s up to 650V. The enclosure of the unit is certified flameproof, and the earth-leakage electrical lock-out circuit and the remote-control/earth-continuity circuit are certified intrinsically safe. The equipment is suitable for any standard supply voltage between 400V and 650V, and can be coupled to units designed to N.C.B. standard, and to other units of the " MU " range.

Among the motors on show will be a working exhibit of a 25 h.p. " WPS " weather-proof or splashproof squirrel-cage motor for general industrial duty. It will be shown operating under a continuous spray of water, the purpose of the demonstration being to emphasise that the motor is suitable for service in damp or wet situations where the more costly totally enclosed or totally enclosed, fan-cooled machines are usually specified.

A motor designed for the iron and steel industry will also be shown—a 25 h.p., 650 r.p.m. " MDX " d.c. machine. Motors of this " MDX " range cover outputs from about 7½ h.p. to 200 h.p. and are designed to conform with the " 600 series " of the American Association of Iron and Steel Engineers, whose standards are now in common use overseas.

General Electric Company, Ltd.

A complete low-pressure rotor assembly for a 60MW steam turbine will be one of the major exhibits shown by The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. This l.p. rotor (Fig. 8) consists of six stages, with twelve wheels, the diameter of the two outers being 8ft. The normal running speed is 3000 r.p.m. A contrast will be provided by a small turbine rotor of the kind used in 325kW marine auxiliary turbo-generator sets. The shaft has a two-row velocity wheel and seven single-row stages ; the normal operating speed is 10,000 r.p.m.

The new G.E.C. gate-end panel (described in our issue of Nov. 18, 1955, page 727), will

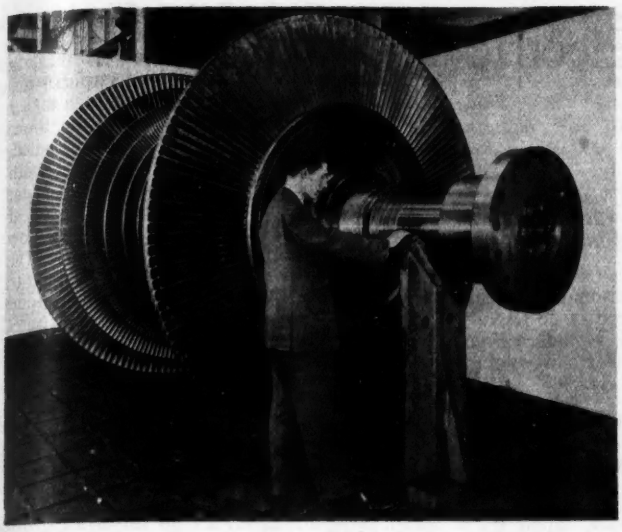


Fig. 8—Low-pressure rotor assembly for 60MW steam turbine—G.E.C.

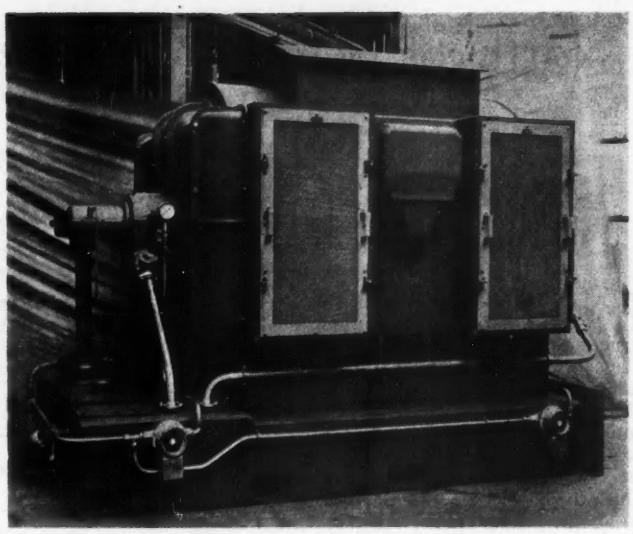


Fig. 10—2050 b.h.p., 2950 r.p.m., squirrel cage motor for driving a boiler feed pump—Bruce Peebles

also be shown. It is primarily intended for use with motors driving coal cutters, loaders and conveyors working at the coal face, being designed for the control of squirrel-cage motors at voltages from 400V to 650V, with full load currents up to 80A. The panel is flameproof, carrying the Ministry of Fuel and Power certificate for Group 1, and is, therefore, suitable for use in fiery mines. In addition, the control circuits and the earth

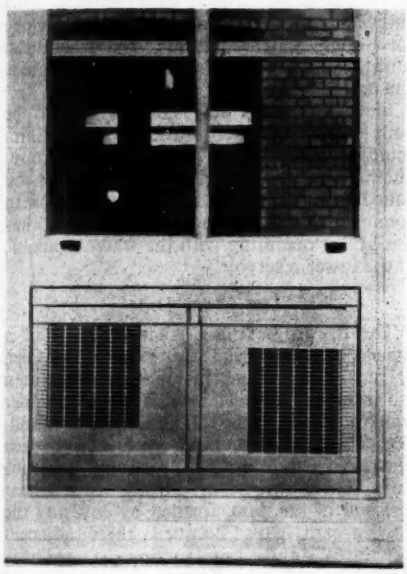


Fig. 9—Room air conditioner with capacity of 12,000 B.Th.U. per hour, operated by 1 h.p. hermetically-sealed motor compressor in a sealed cooling circuit—G.E.C.

leakage electrical lockout circuit are certified as intrinsically safe.

An interesting example of domestic equipment in the G.E.C. display will be a room air conditioner which is intended primarily for export to hot climates, but is available in various modified forms to give it a wider appeal. The air conditioner has a capacity of 12,000 B.Th.U. per hour and employs a sealed cooling circuit incorporating a 1 h.p. hermetically sealed motor compressor. The arrangement is such that a proportion of fresh outside air may be introduced at will and mixed with the recirculating air. Both air streams are filtered by means of a washable nylon mesh filter before passing through the cooling coil and discharging into the room. The complete unit measures 28in by 31in by 18in and can be mounted either flush with the inside wall (Fig. 9), or with the outside of the building or in any intermediate position. Additional items such as an electric heater or a reverse-cycle heat pump are incorporated in some models to cater for requirements in varying climatic conditions.

Bruce Peebles, Ltd.

Generators of medium output made by Bruce Peebles, Ltd., Edinburgh, 5, and intended for direct coupling to steam or gas turbines, will be exemplified by a 1000kW, 11kV, 1500 r.p.m. alternator. This particular machine is designed for gas turbine drive and is equipped with self-contained air filters for the cooling circuit. The main and pilot exciters are mounted in one frame.

Among the motors shown on this stand will be a 2050 b.h.p., 3000V, 2950 r.p.m. squirrel-cage motor (Fig. 10) for driving a boiler feed pump. This motor is designed for "direct-on-line" starting. It is fitted with self-contained air filters and with journal bearings which are pressure lubricated from a pump mounted on the bedplate and gear driven from the motor shaft.

Another exhibit, a new form of tube-cooled squirrel-cage motor, specially developed for oil refinery duty, is shown in Fig. 11. The screen-protected air intake and the

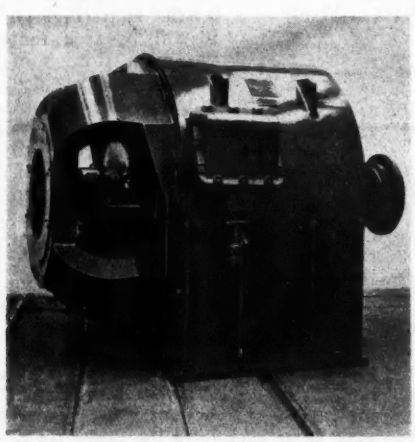


Fig. 11—Tube-cooled squirrel cage motor for oil refineries—Bruce Peebles

ducting carrying the air to the cooling tubes in the stator frame are arranged to form a partial shroud round the bearing bracket at the non-driving end as illustrated.

An interesting exhibit from the company's transformer department will be part of a limb, full-size, of a 120MVA, 132/275kV, three-

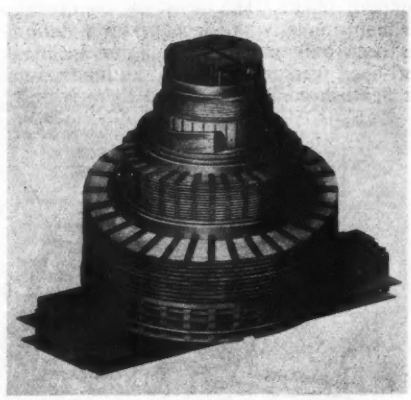


Fig. 12—Part of limb of 120MVA, 132/275kV auto-transformer—Bruce Peebles

phase auto-transformer (Fig. 12). This exhibit will be arranged to allow visitors to inspect the core cooling ducts, the tertiary and tapping windings, the common winding between 132kV and earth, and the series winding between the 132kV and 275kV terminals.

(To be continued)

Future of British Railways Workshops.—A statement was recently made by the British Transport Commission in connection with the future of British Railways workshops and the Railway Modernisation Plan. The Commission foresees that during the next five years, at least, the workshops will, with but minor exceptions, be fully employed if the plan proceeds to schedule. The Commission states that it will rely on outside industry for the manufacture of diesel and electric power equipment and may purchase complete locomotives and other equipment and components from industry. As a general rule, maintenance work will be carried out in British Railways workshops to the extent of their capacity, in accordance with present policy. There will be consultation at all times with the manufacturers to ensure that the maintenance of new equipment supplied by them is done correctly.

North of Scotland Hydro-Electric Schemes

No. VII—THE GLEN SHIRA SCHEME—PART 1*

The Glen Shira scheme is a peak load development, which will yield about 80,000,000kWh annually from an installed capacity of 45MW. It includes pumped storage, an underground pressure shaft, and a roundhead buttress dam.

LATE in 1948 the North of Scotland Hydro-Electric Board started the construction of the Glen Shira scheme in Argyll. The scheme is moderate in size ; it will provide about 80,000,000 units of electricity in a year, but it makes an important contribution to meeting the peak loads in Central Scotland. The first step in this direction was the completion of the Loch Sloy scheme, which operates at an annual load factor of about 12 per cent ; this scheme was ideally suited, by its position and the natural advantages of the site, for peak load development. The Shira scheme possesses the same advantages, but to a more limited extent, and so it has been designed for peak loads, but for utilisation at a higher load factor, of slightly over 20 per cent.

The scheme is noteworthy for the design of the main dam—a roundhead buttress structure—and for the fact that it will be the first of the Board's schemes to incorporate pumping plant. The penstock connecting the main tunnel with Clachan power station has been built underground as an inclined steel-lined pressure shaft, also an innovation for Scottish construction, and there is only one turbo-alternator set in the main power station. This set has a capacity of 40MW and is the Board's largest up to the present ; the installation of a single machine of this size was feasible, since a reasonable operating efficiency over a load range of 50 to 90 per cent can be obtained with a modern Francis turbine, and considerable flexibility is obtainable with the grid system now in operation in this part of Scotland. Thus a very economical power station installation was achieved.

TABLE I—*Power Stations*

	Turbo-generator sets	Installed capacity, MW	Gross head-feet			Average annual production, kWh × 10⁶	Flow at rated capacity and mean head, cusecs
			Max.	Min.	Av.		
Sron Mor	One horizontal pumping set (Francis turbine)	5	151	139	105	6	520
Clachan	One vertical Francis	40	963	926	—	74	630
	Totals	45	—	—	—	80	—

TABLE II—*Reservoirs and Hydrology*

	Useful storage capacity, acre-feet	Top water level, feet A.O.D.	Catchment area supplying reservoir, square miles			Mean annual flow into reservoir, acre-feet	Average annual rainfall, inches
			Direct	Indirect	Total		
Upper reservoir	17,300	1,108	4·59	8·77	13·36	57,070	105
Lower reservoir	1,265	970	0·60	7·52	8·12	32,000	

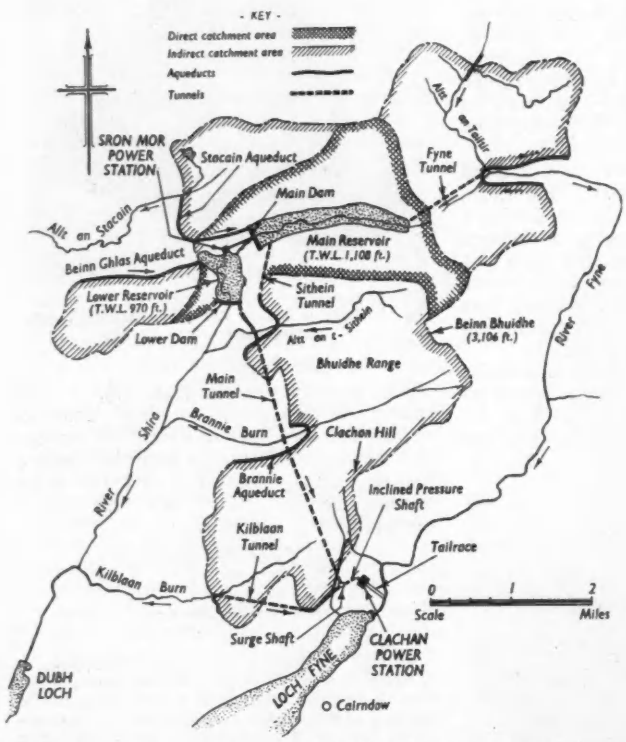


Fig. 1—Catchments and main works of the Glen Shira hydro-electric scheme

Most of the power generated by the Shira scheme will find its way into the grid, being transmitted first to the Inveruglas switching station of the Loch Sloy scheme, but some of it will be used to supplement the output of the small schemes at Cowal and Kintyre, supplying part of Argyllshire, as was explained in the fifth article of this series.

The principal data of the scheme—heads, capacities, and so on—are listed in the accompanying tables, and its layout is shown on the map (Fig. 1). It will be seen that the main storage of the scheme is provided in the upper reservoir. Water is led from this reservoir through the 5MW set at Sron Mor power station into the lower reservoir ; alternatively, the Sron Mor installation may be used to pump water from the lower to the higher reservoir. The main tunnel leads from the lower reservoir to Clachan power station, where most of the power will be generated, as the tables show. The scheme is completed by a system of diversion aqueducts, some leading to the upper reservoir and some to the lower. During wet weather the flow from the lower collecting system will generally be sufficient for the operation of Clachan power station, allowing flow from the upper reservoir catchment to be stored ; at times of low load surplus water will be pumped from the lower to the higher reservoir to avoid spillage from the lower reservoir, the capacity of which is limited, and for re-use through the full head of both stages. When Clachan power station is not in operation flow from the stream intakes at Brannie burn and the surge pond can flow up the tunnel to the lower reservoir. The total storage of the scheme is equivalent to about 25 per cent of the annual output. As with other schemes, compensation water for fishing interests has been allowed, both down the River Shira (5 m.g.d. with spates of 45 m.g.d. on sixteen days between June and September) and from the intake on the headwaters of the River Fyne, where no water will be taken until the flow exceeds 3 m.g.d.

Eleven miles of access roads had to be built before the main works at Glen Shira could be started, and 4 miles of roads were required for access to the outlying diversion aqueducts. Clachan station first went on to commercial load on January 20, 1955, and has since been operating with the water available in the lower reservoir.

THE MAIN DAM

The drawings (Fig. 2) show details of a typical buttress of the main dam of the Glen Shira scheme. The principal data of the dam are listed in Table III, and it is shown under construction in Fig. 3. The dam is a roundhead buttress structure, with thirty-seven buttresses and gravity sections at each end. There will be a spillway section near one end of the dam, formed by covering the downstream gaps between three adjacent buttresses, and constructing a spillway bucket at the toe. The water controls for a scour pipe and the intake to Sron Mor power station are contained in an intake tower between two central buttresses. The power station intake and the scour pipe are built in the same vertical line in the upstream part of the tower, so that one emergency gate may be used to close either the scour pipe or the intake, which are served by a single set of gate grooves. Near the downstream side the two diverge and there is a needle valve controlling the scour pipe at the toe of the dam, and a control gate on the intake pipe.

In the design of this dam a number of alternative structures were considered before it was decided that the roundhead buttress dam would be the most economical one. The alternative proposals included a gravity design, a slotted gravity design to reduce the uplift pressure, and a rock fill design. The

* No. I.—"An Introductory Survey" appeared July 14, 1950; No. II.—"The Loch Sloy Project," July 21, August 4, 1950; No. III.—"The Fannich Project," June 8-15, 1951; No. IV.—"The Mullardoch-Fasnakyle-Affric Project," April 11-25, 1952; No. V.—"Some Schemes for Local Supply," October 16-23, 1953; No. VI.—"The Tummel Garry Scheme," September 2-23, 1955.

slotted gravity dam showed little difference in cost, but the roundhead design was considered more suitable for the Shira site. The rock at the site is poor, and the vertical stress at formation was limited to 7 tons per square foot. The buttresses of the dam are splayed out near the toe to give a more even distribution of load on the rock under working conditions.

In the last article in this series, which described the Tummel-Garry scheme, we included (in THE ENGINEER of September 9th last) a survey of some buttress dams under construction, or completed, on the Board's various schemes. The advantages of these structures were outlined and comparative figures given for principal stresses, dimensions and volumes of the Shira, Giorra and Errochty dams. Errochty dam is, of course, a part of the Tummel Garry scheme and was described in some detail on that occasion. Reference to our earlier description is, however, of interest since Errochty dam is a diamond-headed buttress structure, a variant of the round-headed dam. Both designs aim at the same advantages, so many of the facts mentioned in our earlier article apply equally well to the Shira dam. We do not propose, therefore, to repeat here a discussion of the merits of the round-head buttress design save to mention that for the Shira dam the volume of 260,000 cubic yards of the dam is estimated to be less than that of the comparable gravity dam by 50,000 cubic yards.

TABLE III—*Dams*

	Maximum height-feet	Length, feet	Concrete volume, cubic yards	Earth fill volume, cubic yards	Volume of excavation, cubic yards
Upper reservoir dam: round-head buttress	133	2250	260,000	—	135,000
Lower reservoir: concrete gravity section	58	400	18,000	—	15,000
Earth fill section	53	600	—	80,000	—

Spillway capacities	Main dam	Lower dam
Maximum spillway discharge corresponding to I.C.E. flood committees, normal maximum flood, cusecs	1225	2820
Scour pipe discharge at T.W.L., cusecs	590	1570
Lower dam: maximum discharge of compensation pipe, cusecs	—	46
Discharge of spillway at maximum head of 4ft, cusecs	—	3200

Shira and Errochty are the only two buttress dams in this category which have been built in this country, up to the present, apart from the Haweswater dam (also mentioned in our September 9th issue). The drawings in Fig. 2 show several detailed points of interest in the Shira dam. The "pitch" of the buttresses is greater at Shira than at Errochty (50ft against 40ft 6in) and the individual buttresses are of more massive cross section. At Shira also, adjacent buttress heads were built with a wedge-shaped gap between them; this gap was concreted after time had elapsed for contraction of the "green" concrete in the buttress heads. This method of construction also allows some relative settlement between adjacent buttresses.

Shira dam was designed by methods now fairly well established for this class of structure. The design starts from an application of Schorer's method, and by computations similar to those used for gravity dams. A description of the design of the dam has been published.†

PLANT AT THE DAM SITE

The constructional plant at the dam site includes quarry plant used for the construction of Loch Sloy dam. On completion of that dam the plant was moved from Coiregrogain quarry to its present position adjacent to Glen Shira dam. The aggregate used is epidiorite, excavated about $\frac{3}{4}$ mile from the dam and brought to the crushing and screening plant by a belt conveyor. Quarry-run fine aggregate is being used with a small proportion of natural sand to supplement the quarry's output. The quarry plant was described in our issue of August 4, 1950, as part of the article on the Loch Sloy scheme; the Shira installation can produce about 1200 tons of washed rock a day.

The graded aggregates are stocked in two sets of four aggregate bins, under which there are recovery tunnels with belt conveyors leading to the batching and mixing plant. The concrete is weigh-batched and mixed in two 2 cubic yards mixers. The aggregate is graded thus: 2½in–1½in, 1½in–¾in, ¾in–⅜in, ⅜in–$\frac{3}{16}$in, rock sand, and natural sand. The hearting concrete is mixed with a cement content of 380 lb per cubic yard and a water-cement ratio of 0·7, the specified minimum strength being 1950 lb

† "The Use of Semi-Graphical Methods in the Structural Design of Concrete Dams," by R. M. Kenedi. Glasgow and West of Scotland Association of the Institution of Civil Engineers, February 25, 1949

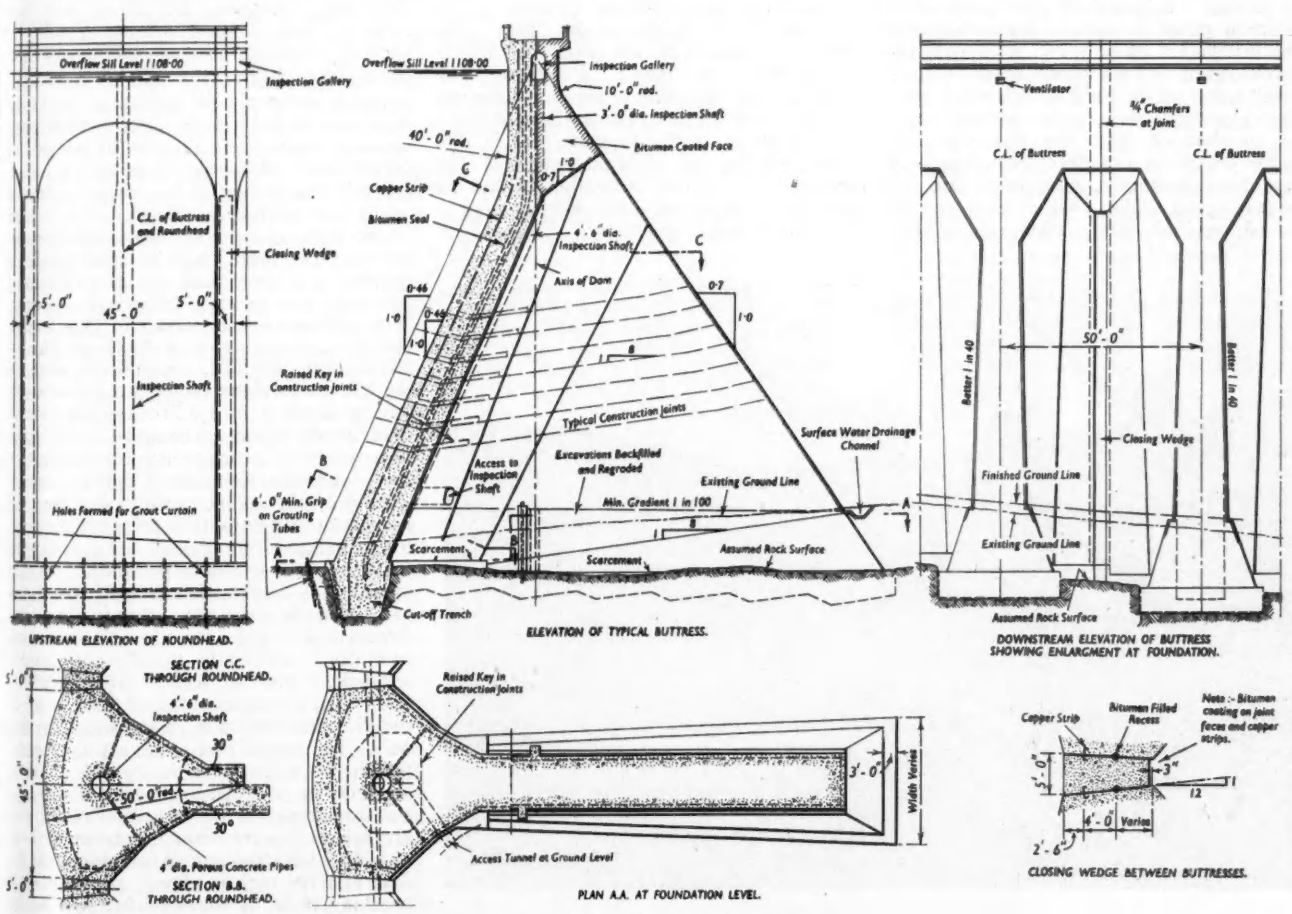


Fig. 2—Constructional details of the main dam

per square inch at twenty-eight days. The plant has an output of about 100 cubic yards an hour, which is quite adequate for serving the two cableways, which are capable of placing about 72 cubic yards per hour. This capacity is based upon nine cycles of each cableway in an hour, each cableway (they are of 10 tons capacity) carrying a 4 cubic yards skip, and covering almost the entire length of the dam. These cableways are also of the same general design as at Loch Sloy, and were described in our earlier article. In the early stages of construction the first concrete was placed in the end buttress of the dam close to the concrete plant, and this buttress was built to a suitable height to form a base for the headmasts of the cableways. At the other end of the site a temporary concrete structure of a substantial nature was built to accommodate the tracks for the travelling tail carriages of the cableways. Excavation for the main dam was carried out while construction of the lower dam was in full swing, and the concreting of the main dam with the plant described above, was not started until 1954, when the concrete section of the lower dam was substantially complete.

A steel penstock, 9ft in diameter and 720ft in length, and built in a trench, leads from the draw-off tower in the dam to Sron Mor power station, which is built on the shore of the lower reservoir, into which it discharges and from which it pumps into the upper reservoir. The pumping set at Sron Mor is described in a later section of this article.

The Lower Reservoir

The main purpose of the lower reservoir of the scheme is to collect the flow from the additional catchment areas below the level of the upper reservoir, which would have been very limited in extent at the upper reservoir level. The reservoir also serves to provide a substantially constant head for Clachan power station, a factor favouring the installation of only one set. With this layout there is an average head of about 100ft acting on the main tunnel, which starts at intake works close to the concrete section of the dam of the lower reservoir. The intake comprises a reinforced concrete structure housing screens, emergency gate and control gate. The control gate can be seated on both sides. It may be recalled that water collected by the Brannie and Kilblaan aqueducts can flow up the tunnel to the reservoir, if the power station is not in operation. Thus, with double seating the gate cannot be damaged if it should be operated when the flow is in reverse.

Fig. 4—Impounding structures of the lower reservoir. On the left is the tunnel intake tower and the concrete dam; the earth fill dam is to the right. The Shira valley and Glen Fyne are seen in the background

The lower dam (Fig. 4) is built in two parts. On the left bank side there is a concrete gravity dam ; there is then a rock outcrop forming a central "island" of high ground, with an earth-fill dam on the right bank side. This choice of dual structure is not without interest in its relation to the nature of the site. The concrete section of the dam is appreciably curved in plan ; it follows this shape to take advantage of the rock outcrops. The bed rock here—an impermeable schist—is overlain by glacial deposits, and in one place, just at the right abutment of the concrete section, the excavation had to be taken to a depth of about 40ft to reach a firm formation. Similarly, a pocket of glacial silt was excavated under the upstream toe of the earth-fill section, and filled with rock spoil deposited in layers and blinded.

The moraine was much thicker on the right bank side of the rock "island," and so an earth-fill structure proved more economical than a continuation of the concrete dam. The earth-fill dam has a concrete cut-off, and a heavily reinforced concrete core wall 18in thick, articulated at its base with a concrete hinge and bitumen seal, as the diagram, Fig. 6, shows. Originally, a sloping clay zone was envisaged, but there was not sufficient clay of good quality at the site and the tenders included alternatives for providing a concrete core.

Construction of both sections of the lower dam was carried out by more or less conventional methods, and calls for no special description. However, there is one other point in the design of the concrete section which is of particular interest. This section of the dam, which plugs the natural course of the river Shira, had to incorporate a spillway and scour discharge in such a way that erosion of the river bed would not occur. The spillway design shown in Fig. 5 was, therefore, evolved from model tests. The inclined apron just downstream of the dam on the left bank (where the drawing is marked "Slope down 1 in 2·3") simply covers the natural rock surface. The spillway discharge next to the left bank which runs down this wall, and the discharge from the centre section of the spillway, which is projected straight downstream, thus form two impinging streams. The model tests indicated that to avoid excessive turbulence, a step averaging 1ft 6in deep (marked *AB* in the drawing), would be necessary, so as to allow one stream to pass under the other, thus reducing turbulence sufficiently to allow a proper hydraulic jump to form. The hydraulic jump then dissipates some of the energy of the discharge before it passed over the first weir. The second weir forms a stilling pool, both for the spillway and the scour discharges, and acts as a measuring weir for gauging the compensation water. These spillway arrangements were necessary because there is a 40ft waterfall just downstream of the dam and the rock is of very poor quality ; breaking back of the waterfall had to be avoided, and the second weir ensures an

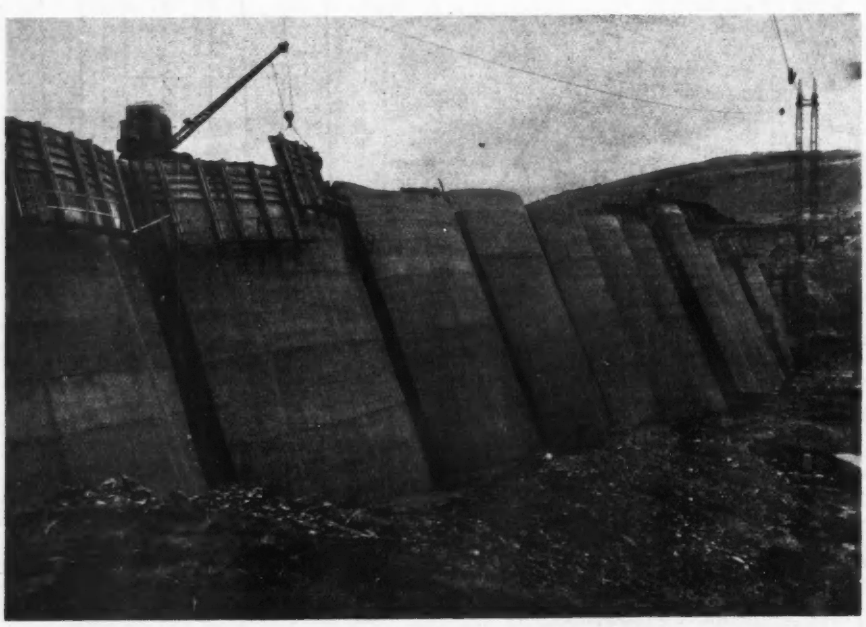


Fig. 3—Construction in progress on the main dam. The roundheads of the upstream face of the dam are shown

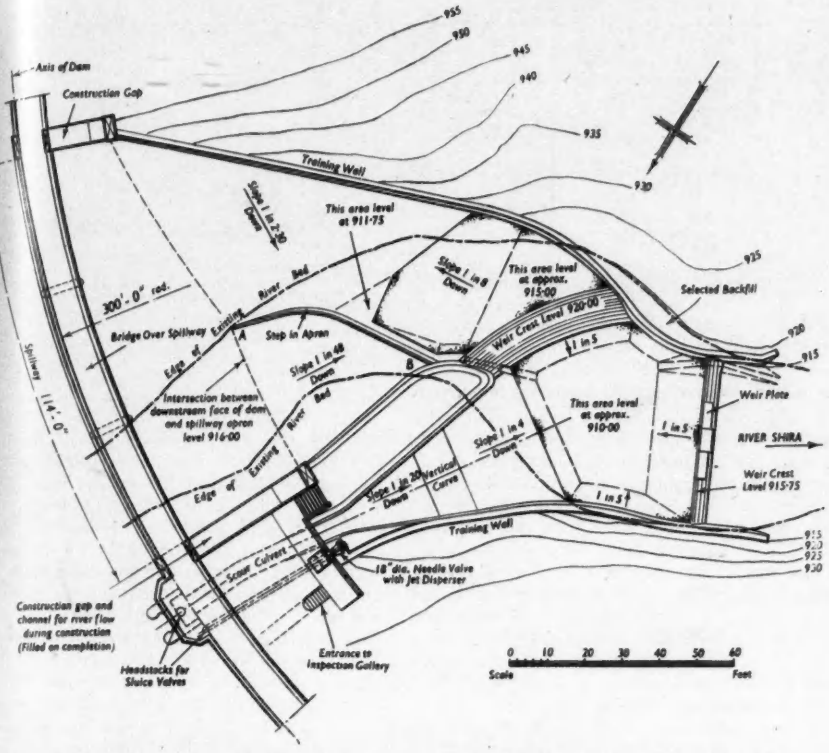


Fig. 5—Plan of concrete gravity dam of lower reservoir, showing layout of spillway and stilling pools

even distribution of flow on to the river bed.

Main Tunnel and Diversion Aqueducts

The main tunnel from the lower reservoir intake has a length of about 4 miles, and has a circular cross section with a diameter of 10ft. The concrete lining is nominally 8in thick, and is generally unreinforced. The arrangement of the surge shaft at the end of the tunnel is shown in Fig. 7; the tunnel also incorporates two stream intakes, one of which leads into the surge pond and one into a point about halfway along the tunnel.

The tunnel was driven from five faces—one at each end, and the others at two valleys crossing the line of the tunnel. The first of these two low places was crossed by a reinforced concrete cut-and-cover section about 1500ft in length, followed by a 10ft diameter steel pipe 296ft long, and the second, by a steel pipe, 10ft in diameter and 648ft long. The rock encountered in the tunnelling was generally schist, and the tunnel was driven in fifteen months; the best weekly rate of progress on one face was 247ft, which was a record at the time. The tunnel excavation totalled 85,000 cubic yards. The light "Swedish" drilling equipment was used for most of the work. Lining was carried out with 200ft long mobile forms, and a "Pressweld" pneumatic placer was employed. A maximum weekly rate of 1020ft was achieved for the construction of the tunnel lining, which was completed in fourteen months. The tunnel driving was completed at an early stage in the construction of the scheme.

The stream intake into the main tunnel from the Brannie aqueduct consists of a sloping pipe which generally runs only partly full, and joins the main tunnel at the steel pipe valley crossing (see Table IV). With intakes such as this it is necessary to exclude air from the flow passing through the turbines, so as to prevent cavitation trouble; the siphon and trap arrangement for evacuating air from the intakes to the pressure tunnel of the Affric scheme may be recalled. At the Shira main tunnel it is expected that a certain amount of air will be entrained, although the fact that the intake pipe generally runs only partly full will allow most of the air in it to escape. Any air finding its way into the tunnel will, however, escape at the surge shaft. The gradual rise in the roof of the expansion chamber may be observed from Fig. 7; thus air bubbles will rise as they pass along the expansion chamber, and travel up the surge shaft instead of being carried down the pressure shaft with the flow. Verification of this behaviour during design was hindered by the absence of scale effect on a hydraulic model, but tests were carried out to find a limiting velocity of flow—about 1·5ft per second, it was found—which allowed the bubbles to rise and escape, and the expansion chamber was designed so that this velocity will not be exceeded.

The surge shaft arrangements are simple, but the change in direction of flow from the tunnel into the pressure shaft may be noted. The surge shaft continues the line and gradient of the pressure shaft upwards, as Fig. 7 shows; surges are contained by the dam in the surge pond. The surge shaft is 20ft in diameter; the expansion chamber is 15ft wide, 232ft long and has a maximum height of 33ft.

Construction of the various channels, pipelines and tunnels of the collecting aqueducts followed the usual practice for such work, but the intakes themselves have some points of novelty. Automatic control of compensation water is to be effected at the River Fyne intake, and the intakes will incorporate self-cleaning screens. In this design the intake weir has a screen in its crest, through which the diverted water flows into the aqueduct. The excess flow passes over the weir and the intake screens, taking with it the debris which normally accumulates on the screens. These designs were examined by hydraulic model tests. There is, altogether, an extensive system of diversion aqueducts in the completed scheme, as Table IV clearly shows. They comprise 3 miles of tunnels and 9 miles of pipes, and trapezoidal concrete-lined channels covered with prestressed concrete slabs. The tunnels are partly lined with concrete; the invert is generally lined, and the extent of the lining of the rest of the cross-section depends on the rock conditions encountered. These aqueducts are designed for a maximum capacity of five to ten times the estimated average flow, according to their length and position.

The Pressure Shaft

A cross-section through the underground pressure shaft which connects the expansion chamber at the end of the tunnel with the power station is shown in Fig. 7. The shaft is 2100ft in length. There is good rock cover varying from about 300ft to 500ft over the shaft. Pressure shafts such as this one have been used on Continental hydro-electric schemes in various countries, often combined with an underground power station. Economies in steel as compared with a conventional penstock result, and the underground power station is sometimes more economical than a surface structure; such designs have been described in the columns of The Engineer on various occasions, and have now found application on other Scottish schemes, underground power stations being at present under construction as part of the Moriston scheme.

Clachan power station is not an "underground" power station in the true sense of the term. Rather it is a "cut-and-cover" structure built actually in the hillside, which has been backfilled over its substantial con-

Table IV—*Tunnel and Aqueduct Details*

	Maximum capacity of aqueduct, cusecs	Length (miles)	Cross sectional dimensions	Construction
Main tunnel	According to load conditions at Clachan power station	4	10ft diameter, circular ...	Concrete lined with r.c. cut and cover length and two steel pipe stream crossings. Slope of tunnel 1 in 278 and 1 in 250
Aqueducts feeding the upper reservoir				
River Fyne aqueduct ...	200	4	6ft 6in by 6ft 6in tunnel, 18in to 33in dia. pipes and open channel	Partly-lined tunnel, 1¼ miles long, supplied by two intakes, piped stream diversions and trapezoidal concrete-lined channel
Allt an Stacain	55	1¼	3ft 9in bottom width; 3ft deep; 1 in 2 side slopes	Trapezoidal concrete-lined channel
Allt an t-Sithein	60	1½	5ft by 6ft tunnel; 15in to 27in dia. pipes; channel 3ft 9in bottom width by 3ft deep, 1 in 2 side slopes	Partly lined tunnel, channel and piped stream diversions
Aqueducts feeding the lower reservoir				
Beinn Ghlas	40	1¾	18in to 36in dia.	Piped diversion to lower reservoir
Brannie	190	1½	Pipes 30in and 21in dia. Channel 6ft bottom width by 4ft deep, 1 in 2 side slopes	Pipes and trapezoidal channel, all connected to main tunnel through junction chamber and 48in dia. steel diversion pipe which joins the main tunnel at the top of the steel pipe crossing of the Brannie burn
Clachan and Kilblaan	140	2¼	5ft by 6ft tunnel, 30in and 21in dia. pipes; channel 5ft 6in bottom width, 3ft 9in deep, 1 in 2 side slopes	Partly lined tunnel, channel and piped stream diversions leading to the surge pond

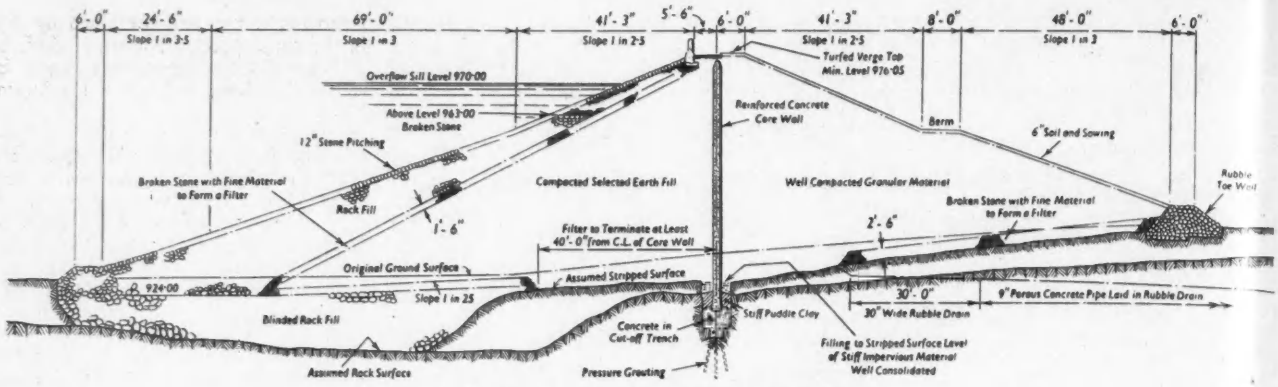


Fig. 6—Cross section of earth fill dam of the lower reservoir

crete arch roof. Thus, the pressure shaft has sufficient rock cover to extend right up to the turbine inlet valve, so the maximum advantage is achieved from its use. The cut-and-cover design, we understand, gave a slight economy over a conventional surface design. In fact, costs for both designs—the one actually built and a conventional surface penstock and power station—were checked at the tendering stage and there was little difference between them. But the pressure shaft layout allowed a significant economy in steel, and at the time when this work was started there was a national shortage of steel and economies were being urged in all constructional work. A further point considered to be in favour of the present design was that no pipeline would be visible, and the entrance portal of Clachan power station would be very unobtrusive, as compared with a normal power station building.

The pressure shaft was excavated from the bottom. A quantity of spoil was kept in it, over which access to the face was obtained. The spoil provided a convenient working platform close to the face. Progress was slow, but the method was economical, and the rate of progress was not critical to the whole scheme. On completion of the excavation, an inclined railway was laid down the shaft for placing the pipes and carrying out the concreting. At the bottom level the shaft turns in the horizontal direction and runs horizontally to the turbine inlet valve at the power station. There is no water control gear at the top of the shaft. During construction the tunnel adit leading to the surge shaft was served by an inclined railway.

The design of the pressure shaft was described at a recent meeting at the Institution of Civil Engineers by Mr. J. A. Banks during the discussion of a paper on underground power stations. The following paragraph is abstracted from Mr. Banks' remarks.§

The concrete walls of Clachan generating station below main floor level had been poured hard against the rock, he noted, and the reinforced concrete columns and crane girders, which carried a 150-ton overhead travelling crane, had been anchored into the rock both longitudinally and transversely. There was an inner lining of brickwork and a suspended ceiling, the main roof having been formed by a reinforced concrete arch springing from skewbacks cut into the rock, and with that internal lining and ceiling there was a complete clearance cavity between the internal structure and the rock itself above the main floor level. The rock in the power station and through which the pressure shaft had been driven was quartz-schist, and the inclined shaft had been driven at an angle of 39 deg. to the horizontal (1¼ horizontal to 1 vertical). That slope had been adopted for a variety of reasons, but one was that the inclination was just a little in excess of the natural angle of repose of rock spoil, so that the spoil was more easily removed. It so happened that that inclination was almost normal to the planes of cleavage in the rock, so that by driving normal to the planes the whole length of the tunnel had in fact been successfully completed without any support at all, a very distinct advantage. Excluding the approximately level section approaching the generating station, the depth of the pressure shaft below ground provided a weight of overburden measured vertically above the diameter of the shaft sufficient to balance the water pressure at any point. The lining was of mild steel to British Standard 15 (ultimate strength 28/33 tons per square foot). The basis of the design had been as follows. It had been taken as a first approximation that the stress in the steel lining should not exceed the yield point of the steel, assuming that there was no assistance from cover or other support from the rock itself. Consideration had then been given to the effect of fissures of varying depth in the rock surrounding the encasing concrete and the results had indicated that it was conservative to design on the basis of yield point. The lining had also been considered for the effect of external pressure with the shaft empty. It seemed to him that analyses on that aspect were largely empirical; he wondered whether some addition to the normal thickness of the lining and attention to thorough packing and grouting behind the lining was not the direction in which most attention should be given. That, in fact, had been the procedure adopted at Clachan, and perhaps for that reason, being a little conservative, the saving in steel had not been quite so great as applicable to the general case. Actually, there had been a saving of 350 tons of steel in the Clachan pressure shaft; there were about 700 tons of steel in the shaft. The thickness of lining ranged from $\frac{7}{16}$in at the surge gallery to $1\frac{9}{16}$in at the generating station. The diameter was generally about 7ft 6in, but increased to 8ft towards the surge gallery and reduced to 6ft at the power station. The reason for the reduction was governed by the maximum thickness of plates both for bending and for welding. The joints were flange joints where otherwise overhead welding would have been involved and a changeover to welded joints was made part-way up the inclined shaft arbitrarily where the static head was of the order of 600ft. At the power station itself the lining had been designed for the full static head of 960ft, plus allowance for water hammer. Concrete casing had been placed by pump as each two pipe lengths of the lining (48ft) had been completed. The strength of the lining against external pressure had been investigated for a four and six-lobe collapse, and grouting had been specified to range in pressure from 25 lb to 200 lb per square inch, according to the thickness of the lining and the rock cover.

(To be concluded)

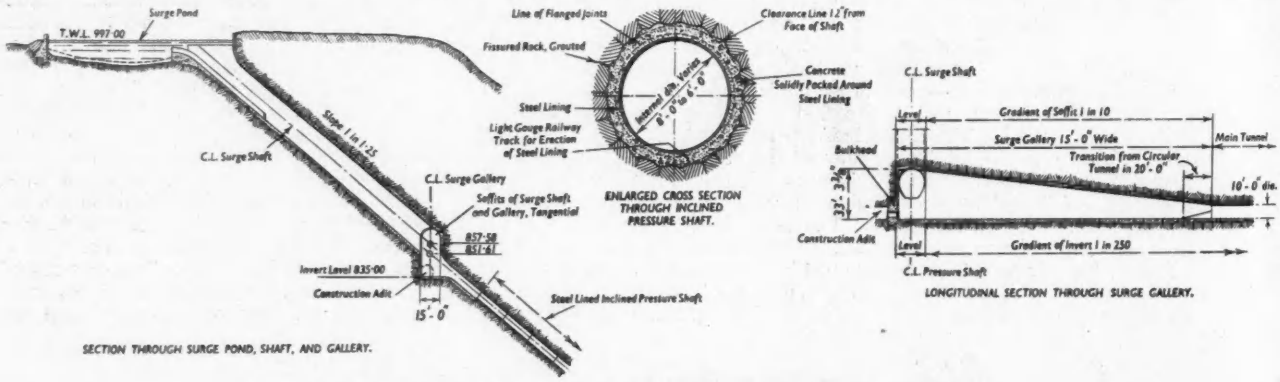


Fig. 7—Constructional details at junction of main tunnel and inclined pressure shaft

§ "Present Trends in the Design of Pressure Tunnels and Shafts for Underground Hydro-Electric Power Stations," by Charles Jaeger, *Proceedings of the Institution of Civil Engineers*, Vol. IV, March, 1955, No. 2.

Materials for Nuclear Power Engineering

AT a meeting of the Institute of Metals on Wednesday, April 11th, the following papers were presented: "Metallurgical Research and Development for Nuclear Power," by H. K. Hardy, "Metallurgical Research Problems Associated with Nuclear Energy," by J. G. Ball, "Selection of Canning Materials for Reactors Cooled by Sodium/Potassium and Carbon Dioxide," by A. B. McIntosh and K. Q. Bagley.

Dr. Ivor Jenkins (vice-president) who acted as rapporteur for these papers said: The metals of direct interest in the nuclear power programme, are summarised by Ball in his Table I. The major metallurgical problems are associated with the fuel and its sheathing—that is, the fuel element—and this is the general theme of the three papers presented to-day. The metallurgical problems associated with the fuel element may be conveniently considered under the headings listed by Ball, namely: (1) irradiation stability, (2) thermal stability, (3) sheathing materials, (4) corrosion, (5) fabrication. Dealing first with irradiation stability, in the fission process considerable damage to the fissile material is caused because of the increased volume of the fission products and the severe local distortion of the lattice resulting from the energy released in the fission process. Two of the major effects are evidenced by wrinkling or growth of the uranium bar, and by swelling with a decrease in density. The former effects are thought to be due to the anisotropy of alpha uranium which is the stable form up to 670 deg. Cent. Irradiation of uranium having a preferred orientation will result in a change of shape of the uranium bar as a whole, and the illustrations in the paper by Ball show that this effect can be most spectacular. Wrinkling and growth is reduced in a randomly orientated fine grain structure, which is obtained by quenching from the beta field. Two theories are described by Ball to explain these effects, one based on a twinning and slip mechanism, and the other on a diffusion process. These theories are widely divergent, and clearly this is an aspect for further investigation and discussion.

It is, perhaps, significant that these effects are markedly dependent upon the purity of the material, and one might make the general observation of all the work on uranium that the properties of the very pure material have yet to be determined. This is a further aspect which might profit by discussion.

The swelling which occurs on irradiation is associated with the gaseous fission products xenon and krypton. This effect is more pronounced at high temperatures and at high percentage burn-up of uranium, and is due to the collection of the gaseous fission products as discrete bubbles within the uranium. The nature of the diffusion process leading to bubble formation is intriguing, as the observations on the diffusion of argon in silver indicate. There appears to be, at higher temperature, some correlation between the pressure generated in the gas bubbles and the creep strength of the material. However, the picture at lower temperatures—which may obtain in gas-cooled thermal reactors incidentally—is not so clear, and an investigation of the creep behaviour of alpha uranium under irradiation is necessary. This is a further aspect which, again, might benefit from discussion.

Ball concludes that a strong isotropic alloy should exhibit good resistance to irradiation damage, and here there is much scope for work on alloys. From this point of view, uranium-molybdenum alloys have shown much less swelling than uranium itself, but, unfortunately, molybdenum is undesirable on nuclear grounds. The interesting point is made that irradiation can affect the position of alloy phase boundaries. May this be due to displaced atoms and vacancies behaving in a manner similar to that of alloying elements?

Swelling can be inhibited by encasing the fuel in a can of sufficient strength. Here the problem is that of a compromise between adequate strength of the sheathing material and an acceptable loss of neutrons in it. Alternative proposed solutions to this problem include the dispersion of the fissile particles in a non-fissile matrix, and the development of a rigid skeleton of uranium carbide in a sintered uranium compact. This raises the possibility of utilising as fuels ceramics which might behave better under irradiation than metals. The effect of irradiation on the properties of fissile and non-fissile materials is a field for study which is still largely unexplored, particularly at neutron flux densities comparable to those which will obtain in power reactors. I was, however, assured, just prior to the meeting, by Mr. Ball that much work on a purely experimental basis has been going on on neutron flux densities comparable to what may be expected in industrial power reactors.

Turning now to thermal instability, the fuel element may be unstable at elevated temperatures due to the effects of thermal cycling on the external shape of the uranium, and interaction between the fuel and the material of the sheath. The large changes in shape of uranium resulting from thermal cycling are remarkably similar to those arising from irradiation damage, and it would be interesting to know to what extent the two effects can be correlated. Good thermal contact is desirable between the sheath and the fuel in order to ensure heat transfer efficiency, but at the same time any reaction should not be sufficiently rapid to lead to penetration of the sheath by the uranium during the required lifetime of the element. Most sheathing materials have thermal expansion coefficients markedly different from that of uranium, and this can give rise to an effect known as "ratcheting," which causes failure of the sheath. It may be overcome by bonding the fuel to the sheath. The merits of bonding in relation to heat transfer, mechanical and thermal stability are perhaps somewhat debatable.

The physical and nuclear properties of a sheath have already been defined. The mechanical properties should be consistent with the stresses imposed upon it. It must be strong enough to support and to locate the fuel, yet be sufficiently ductile to relieve high local stresses caused by dimensional changes in the fuel. Factors determining the choice of sheathing materials for reactors cooled by either carbon dioxide or by liquid metal are described in a most comprehensive manner by McIntosh and Bagley, who make the interesting observation that many of the requirements of materials in a reactor are independent of the reactor type. In so far as gas cooled thermal reactors are concerned, choice of canning material is adequately summarised in one of their diagrams, where the discriminating factor employed is the ratio of the neutron absorption cross-section to ultimate tensile strength. The extent to which the application of this factor is valid is, perhaps, a matter for discussion. The outstanding advantage of beryllium and zirconium at temperatures from 300 deg. to 500 deg. Cent. is obvious from the charts, but it is interesting to note how certain of the materials considered interchange their relative positions depending upon the temperature. In general, the controlling factor after neutron absorption requirements have been met is that of oxidation resistance. For temperatures up to 400 deg. Cent., aluminium, magnesium, stainless steel and zirconium are satisfactory in CO_2, but at 500 deg. Cent. only aluminium and stainless steel possess the necessary oxidation resistance. Interesting effects associated with the deposition of carbon on magnesium and stainless steel are noted in this experimental work, whilst Ball discusses phenomena associated with zirconium and its alloys. Whilst the effect of water vapour in accelerating oxidation by carbon dioxide is noted, it is clear that the mechanism of this effect is by no means clearly understood. One may wonder to what extent other trace impurities, which might arise from other sources in an industrial power reactor, also have significant effects in this respect. An interesting aspect is that of the possible corrosion of magnesium in CO_2 resulting from the carry-over of non-ferrous material in the coolant from other parts of the system, probably from the heat exchanger.

Similar considerations to the foregoing in relation to the requirements for a liquid cooled "fast" reactor limit the number of possible canning materials significantly, as shown by McIntosh and Bagley. They demonstrate, as a result of their experimental work, that the choice of canning materials to contain liquid or solid uranium is in the order tungsten, tantalum, niobium, zirconium, titanium and molybdenum, with only the first two elements showing absence of reaction just below the melting point of uranium. It is considered that developments in "fast" reactors may well depend upon the preparation of pure tungsten in the form capable of fabrication. Coatings of refractory materials such as magnesia and alumina effectively prevent attack by uranium. This in itself is a matter for interesting discussion. Strengthening of container materials, however, must be considered by alloying with suitable metals rather than by interstitial atoms such as oxygen or nitrogen, because uranium will scavenge these elements from the sheathing material. In so far as compatibility with the coolant is concerned, this does not appear to be a limiting factor in the choice of a sheathing material. On the other hand, the marked influence of oxygen on the corrosion rate is noted, and the oxygen concentration in the coolant should be maintained at the lowest possible level. In the liquid metal field thermal gradients can result in the mass transfer of material through the liquid due to differences in solubility at various points in the system. Mass transfer is one of the major problems associated with the use of liquid metals.

However, whilst a considerable amount of specialised information has been built up in relation to the performance of sheathing materials in various corrosive media and the compatibility of such materials with the fuel,

little information is as yet available on the effect of irradiation, particularly at high flux densities, in these systems. The possibility exists of irradiation affecting the kinetics of a chemical reaction or of promoting the breakdown of protective surface films which otherwise restrict corrosion. Similarly, irradiation might significantly affect the strength and creep resistance of non-fissile materials, and here again there is obviously considerable scope for further study and discussion.

The fabrication of the fuel element probably commands, as Hardy and Ball say, most of the metallurgical effort in nuclear energy research and development. Special techniques have to be employed and devised for the handling of the highly reactive materials involved and for their fabrication into forms which are often not quite conventional. Manufacturing techniques may include vacuum arc melting; the integral bonding of fuel and the sheathing, either by casting or rolling; the use of powder metallurgy methods, which, in view of the reactive nature of the elements involved, present particular problems in the handling of fine powders; and specialised welding processes. Dominating the whole of this scene is the need to work to a somewhat rigid timetable if the national programme for reactor development is to be successfully implemented. The paper by Hardy illustrates very clearly the extent to which research and development work allied to a particular reactor design must be tailored and accommodated in a rigid timetable with its extensive and thorough inspection and proving of materials and design. Some may perhaps question the scientific merits of conducting development work under such conditions, but at least it does ensure a constant stimulation, is realistic in relation to the national requirements, and is probably inevitable in any case in a new field of technology which remains so very fluid whilst it is being exploited. It does, however, emphasise how essential it is that research work proceeding in parallel with development work in this field should be aimed at establishing basic principles on which technical decisions can be made with confidence.

Discussion

Dr. L. Wyatt (United Kingdom Atomic Energy Authority, Risley): The extremely competent and exhaustive papers which Dr. Jenkins has reviewed so well have shown that the metallurgical work leading to the design and construction of a reactor may be divided into three sections. First, there is the general research, which should be as free as possible within the framework of a general association with reactor problems. Secondly, there is a feasibility study, which should be approached by the selected people with an absolutely open mind. At the end of the feasibility study starts what from the point of view of the metallurgist can best be described as the process of discounting research forward. This means that he tells the engineer that if he proceeds along the lines laid down by the feasibility study he will get the answers to his problems at the time he needs them. It is only from the end of the feasibility study that a rigid timetable is necessary. It may be that departure from this rigid timetable will be found to be necessary later. If this is so, it means that the feasibility study has been done wrongly. I think I can say that in general in the U.K.A.E.A. we have not suffered from this problem yet, but I should like to take a little of the time of the meeting in describing more particularly some of the researches and developments which have been described by Messrs. Ball and Hardy.

The feasibility study for the Calder Hall reactors really started on March 6, 1951. Fortunately, we had, because of our experience on the Windscale's reactors and the basic research that we had been doing, a considerable background of research, particularly that associated with the behaviour of metal under irradiation. As Mr. Ball's paper describes, by then we had pretty well understood the problems, although there are still features which require further explanation. We had up to that time irradiated various specimens of metal and found growth and breakage exactly as Mr. Ball has described. It appeared to me that a lot of this could be explained by postulating that the grains lengthened in the 010 direction. The most probable reason for this happening would lie in the stresses caused by the expansion of the uranium round the fission spike. The fission spike is capable of heating about 10,000 atoms of uranium round it in the gamma phase. This causes a great increase in volume. Whether this was so or not, if this expansion was causing the growth it would be associated with the mechanism of deformation of uranium, and this mechanism of deformation alters very significantly between room temperature and 500 deg. Cent. This was all we knew, but, fortunately, Mr. Pugh had made some single crystals for us. They took the form of metal strips. They are aggregates of fairly large crystals. We started to irradiate at 200 deg. and 500 deg. Cent. While these strips were in the pile Mr. Pugh thought the matter out rather more clearly and suggested that the irradiation distortion might be associated with twinning and, if so, we should not expect a difference in growth between 200 deg. and 500 deg. Cent.

On irradiation at 200 deg. Cent. a considerable warping took place at the grain boundaries. We measured the lengths of these crystals by putting Vickers impressions at various positions along the length and measuring the length before and after irradiation, and we found that not only did the crystals at 200 deg. Cent. distort in that way, but they grew. When you grow crystals of this kind you get a preferential arrangement of 010 in the longitudinal direction. For most of the crystals the 010 direction was longitudinal, but there was a considerable variation from this and by calculation we were able to show that these crystals had grown exactly as though the growth were in the 010 direction and the contraction was in the 100 direction. The crystals at 500 deg. Cent. did not move at all.

We next studied what happened at high temperature. I calculated what might be expected to happen to uranium on irradiation; I got a curve showing that one might expect very high growth at high temperature and practically negligible growth round about the lower temperatures. As I think the papers show, it was found that uranium grows in the region of 600 deg. Cent. much more than one would expect from that curve. Experiments are under way which show that the creep strength of uranium at low temperatures decreases significantly on irradiation. I think that is the explanation for that.

The gas cooled thermal reactors are based on natural uranium. This was largely due to the foresight of Sir John Cockcroft. If you try to build up natural uranium on the basis of the published prices of U.235, allowing no value at all for U.238, you will see what an advantage, economically, it is from the point of view of fuel costs to build a reactor based on natural uranium, but to twelve people sitting round a table at Harwell in 1951, the limitations which it imposed were far more evident than its economic advantages. In the absence of heavy water, which is extremely expensive, and in the absence of beryllium or beryllia, which are also extremely expensive, the reactor design is just about fixed by the natural uranium. It must consist of a series of rods roughly 1in in diameter in a graphite matrix, and the coolant channels must be round the rods and longitudinal with them. There is no room for them to go anywhere else. Apart from uranium and graphite, you must have practically nothing else there, at least nothing that absorbs neutrons to any consequence. There is a further limitation, too, that it is extremely difficult to design a pressure vessel in any other way than vertically. If you try to lay it horizontally, you will have a high expansion of the steel at one end and a low expansion at the other. The French have managed it on a small reactor, and the Americans have projected such a design, but pressure vessel considerations in England have tied us to the vertical reactor. Consequently, there is our main reactor design fixed. The neutron economy fixes our cans to a few metals—magnesium, steel, zirconium, aluminium and beryllium. Also, our coolant is fixed to a gas, which could be hydrogen, helium, steam, nitrogen, CO_2 and methane. Our temperatures were fixed because we had to provide an outlet temperature which the steam generators could use. This pretty well fixed the whole thing. Hydrogen and steam were ruled out by reaction with uranium, cost ruled out helium, neutron absorption and poor heat transfer properties ruled out nitrogen, and probable reaction under irradiation ruled out methane. For the can, difficulties of fabrication ruled out beryllium, doubts about coolant reaction ruled out zirconium, reaction with uranium ruled out aluminium, and neutron absorption ruled out steel. This left us with magnesium and carbon dioxide, which are compatible with each other and with uranium.

Dr. W. E. Dennis (Chief Metallurgist, G.E.C.-Simon-Carves Industrial Atomic Energy Corporation): To me, the greatest value of the papers lies in the way in which, by illustration, they show step by step how the metallurgy of a fuel element is developed. In particular, they illustrate the entirely different approaches to the problem used during these consecutive stages of development. I am sure that this detailed account of the method evolved by the Atomic Energy Authority for proceeding from research to reality will be particularly welcomed by the industrial groups which have only recently entered the field. There are now more than ten comparatively large metallurgical laboratories in this country engaged almost exclusively on work for the nuclear power programme. The total annual supply of graduate metallurgists for the whole of British industry remains at little more than 100. Co-ordination and collaboration to ensure the proper application of available effort is, therefore, of primary importance.

There is one point that I should like to raise regarding the work on the oxidation of magnesium reported in the papers. Mr. Ball refers to results showing that small additions of beryllium and calcium raise the oxidation resistance of magnesium, while Mr. McIntosh reports that maximum oxidation resistance is obtained with pure magnesium. I believe that this apparent anomaly arises from the fact that the Harwell work by Huddle was done under an atmospheric

pressure of zero, while the other work was done under a pressure of 8 atmospheres.

Mr. G. W. Horsley (Senior Scientific Officer, Metallurgy Division, Atomic Energy Research Establishment, Harwell): My remarks concern what one can do about controlling or minimising the oxygen concentration in a liquid sodium coolant circuit, in view of the excessive corrosion often caused by oxygen contaminated sodium. The ways in which oxygen, as dissolved sodium monoxide, may enter the coolant circuit are: (1) during initial charging procedure; (2) by reduction of oxide films on the walls of certain parts of the circuit; (3) by continual leakage into the system through pores, micro-cracks, seals and glands, &c. When certain constructional materials are used, a "cold trap" for sodium monoxide can be placed in the circuit, which, as far as is known at present, will cope satisfactorily with all three sources of oxygen. However, in certain types of sodium-cooled reactors it may be necessary on neutron economy grounds to use constructional materials such as zirconium to which, because of the high free energy of formation of zirconia, a cold trap would act not as a sink for, but as a source of, oxygen. In this case it looks as if the reduction of the activity of sodium monoxide dissolved in the sodium may have to be effected by a combination of physical and chemical methods. Possible ways that may be considered for starting with a very low concentration of sodium monoxide in the sodium are: (*a*) the initial charging of the system with high-purity sodium produced by either vacuum distillation or gettering with, say, magnesium followed by filtration; (*b*) the removal before charging of those oxide films in the circuit, by either reduction with hydrogen, pickling or abrasion, which would probably be reduced by sodium. To maintain an extremely low concentration of sodium monoxide in the sodium in the face of leakage of oxygen from the atmosphere into the sodium circuit a further variety of expedients that might be considered are:

(*a*) The inclusion of a "gettering" bed of some material (e.g. Be, Th, Zr or Ti turnings) in the system which would not only initially soak up the oxygen quicker than the rest of the components in the circuit, but also hold on to it permanently.

(*b*) The continuous introduction of gettering material into the circuit that will dissolve in the sodium (e.g. Mg or Ca), at a rate sufficient to cope with the leakage rate. The oxides formed, MgO or CaO, whichever it may be, could then be removed by a "cold trap."

(*c*) The designing of the reactor so that the rate of creation of gettering material is sufficient to deal with the leakage rate. That this may be feasable is shown by the fact that when the concentration of Na^{24} has been built up to a sufficiently high level by a continuously applied thermal neutron flux of 10^{14} neutrons per square centimetre per second the rate of creation of magnesium will be about 4 p.p.m. per day. This small quantity should theoretically be able to getter a leak rate of 2 cubic centimetres oxygen per litre irradiated sodium per day.

Dr. C. Edeleanu (Brown-Firth): We have been told a lot about the compatibilities of uranium. It strikes me that if there is about 1 per cent of boron present there will be a lot of other elements present, and I wonder whether anyone can say whether these new elements may affect the compatibility with uranium of the materials about which we have heard.

Mr. S. S. Smith (Imperial Chemical Industries, Ltd., Metals Division): Throughout the papers the emphasis has been on the fuel elements. In 1942, when work started on sheathing in this country, all that we seemed to require was a cylindrical can in aluminium which we could seal effectively and which would have adequate strength. We were much more concerned with the strength than with the physics or metallurgy of the material inside. The American body, the Atomic Industrial Forum, long ago made the point that the fuel element should have the highest priority in investigations in the nuclear field. I think that has emerged to-day, and I think the Institute will probably play a part in determining the pattern of future development.

Dr. S. G. Bauer (Rolls-Royce, Ltd.): It has become evident that the main part in the future development of atomic energy has to be played by metallurgists. Metallurgical problems dominate the whole field. To-day the physics are largely known. In some ways I feel a little distressed at seeing so much modesty displayed here by metallurgists. They give the impression that they sit quietly in the laboratories. The engineers by a certain date had a design study and, like good boys, they went ahead and tried to produce at the right time the answers to the questions put to them.

I make the plea that the metallurgists should take the bit between their teeth. They should not wait for the engineers to ask the questions and then produce the answers. The metallurgists should take the trouble to learn the not very difficult bit of engineering which is involved in the reactor business. As far as fuel units go, it is always the same problem of removing heat at reasonable ratings. They should make creative suggestions as to what, on the basis of their own knowledge, work and fundamental research, can be done, and tell the engineers how they should set about designing the reactors, with the full metallurgical knowledge which is available to-day, not letting the engineers proceed with out of date knowledge and thus becoming three to five years behind in the projects.

Dr. B. R. T. Frost (Senior Scientific Officer, Metallurgy Division, Atomic Energy Research Establishment, Harwell): In Mr. Ball's paper many of the disadvantages of using solid fuel elements are mentioned, such as the swelling problem and the growth problem, and an obvious answer to these problems is to disperse the fissile material in a fluid medium. There are three possible fluid media which spring to mind. First, water can be used as a solution, and the Americans have successfully operated this. The second possibility is fused salts. The third possibility is liquid metals. Liquid metals are superior because of their lack of damage under radiation conditions and because of the possibility of going to much higher temperatures with them. The choice of possible liquid metal fuels is severely limited. One is faced with two possibilities. One can use either a solution of fissile material in a liquid metal or a suspension. The advantage of using a solution is that the fissile material is homogeneously dispersed throughout the core of the reactor and no problems of control and kinetics, due to not knowing where the fissile material is, are introduced if one uses a solution. The solvent for fissile material should obey a certain number of requirements. It should have a low melting point to make reactor starting up a simple operation, and a high boiling point to avoid vaporisation troubles in the reactor. It should have a low cross-section for neutron economy, and it should have reasonable solubility in relation to uranium. The properties are melting point, boiling point, solubility of uranium at 500 deg. Cent., and thermal cross-section. Possible metals are lead, tin, bismuth, sodium, lithium, mercury and gallium, all of which have low melting points, these being 327 deg., 231 deg., 271 deg., 98 deg., 179 deg., −39 deg., and 30 deg. Cent. The boiling points are 1737 deg., 2270 deg., 1477 deg., 883 deg., 1317 deg., 357 deg., and 1983 deg. Cent. The figures for solubility of uranium at 500 deg. Cent. are 0·02, 0·005, 0·09, infinity, 0·01, 0·25 and 0·1. The cross-sections are 1·7, 0·6, 0·032, 0·49, 0·67, 0·360 and 2·8. Therefore, there are only two possible solvents with anything like appreciable solubilities of uranium. They are bismuth, with a very low cross-section, and mercury, with a very high cross-section, which rules it out. Therefore, as mentioned in Mr. Ball's paper, bismuth is the favoured element for consideration as a liquid fuel medium.

The solubilities of the three fuel materials, thorium, uranium and plutonium, against temperature at 800 deg. Cent. are plutonium about 15 per cent, uranium about 7 per cent, and thorium about 1 per cent. At 500 deg. Cent. the figures are 2 to 3 per cent, 0·9 per cent, and about 0·1 per cent. The significance of the figures is that at reasonable operating temperatures one has to use highly enriched uranium to make a thermal reactor work, and this is one reason why liquid metal fuel reactors have not received a great deal of attention in this country up to now and are only just receiving attention in America. So one can, on theoretical grounds, make a liquid metal fuel reactor with a true solution in bismuth provided that the uranium is highly enriched.

If one wants to make a breeder reactor one has to use a thorium blanket. The solubility being slow, one has to use a slurry, D_3B_5 and B_1. The other possibility is a fast reactor based on plutonium fuel, in which one has to go to fairly high temperatures to achieve criticality, in which case one would use a natural uranium or a depleted uranium blanket, and this probably would also have to be slurry at UBI_2 suspended in bismuth: this is one of the large stumbling blocks to the development of liquid metal fuel reactors, all these blanket slurries which do peculiar things being binary systems in which the solid-to-liquid ratio varies with temperature and the solid particles undergo considerable growth and also tend to deposit at cold parts of the system and so on. There are therefore numerous technological problems to be overcome.

Mr. Ball and Mr. McIntosh replied briefly.

AIR LINER TURBINE CONVERSION.—On February 9th there took place the first flight of a Convair-Liner 340 converted by its owners, D. Napier and Son, Ltd., to carry "Eland" turbo-prop engines. The aircraft was originally designed for an alternative turbine installation and a version with 3750 h.p. Allison engines is at present flying freight in the U.S.A. Napier has retained the main fireproof bulkhead of the original radial engine, so that the nacelles are much larger than the engines require, but the conversion is intended to be applied to aircraft already in service. Nevertheless, approximately a ton of weight is saved in the conversion and about 2200 h.p. more provided in the case of N.El. 6 engines. The take-off weight increases from 47,000 lb to 53,200 lb, allowing 12,880 lb payload to be carried a stage distance of 1220 miles instead of 290 miles. The cruising speed will be increased by 45 m.p.h. and the level of noise and vibration lessened. "Spraymat" ice protection has been applied to the spinners and air intakes of the new installation. It is intended to carry out route proving trials in Europe and the tropics before flying to the United States, with a view to obtaining a full Certificate of Airworthiness and having this recognised by the Civil Aeronautics Administration. The aircraft manufacturers are reported to be interested in the application of similar engines to their 440 "Metropolitan."

Engineering and Scientific Applications of Digital Computers

A convention on digital computer techniques was held at the Institution of Electrical Engineers, London, last week, from April 9th to 14th. The opening session, under the chairmanship of Sir George H. Nelson, the president, began with an address by Sir Cyril Hinshelwood, president of the Royal Society, and continued with an introductory lecture by Professor F. C. Williams. A number of general sessions and specialist sessions were held in parallel. The general sessions dealt with engineering and scientific applications of digital computers, business applications, applications to industrial control, and construction and performance of digital computers. The specialist sessions covered numerical analysis, logical design, rapid access storage, magnetic tape, and circuit techniques and components. Visits to digital computer installations were made on April 13th and 14th.

CONSIDERABLE progress has been made in the development of digital computers since the first general-purpose digital computer came into full operation in this country nearly seven years ago. Interest in these computers has since widened to include new applications in business, process control, and language translations and the older applications in scientific research and engineering design are well understood. Nevertheless, the number of computers in use in this country remains very small. It was to help to remedy this defect that the Institution of Electrical Engineers held a convention on digital computer techniques last week. Its main object was to encourage the greater application of the technical effort which is needed to take full advantage of the potentialities of computer techniques.

Three major conventions had previously been held in Great Britain : at Cambridge in June, 1949, at Manchester in July, 1951, and at the National Physical Laboratory in 1953. The recent I.E.E. convention was arranged by the Institution in collaboration with the D.S.I.R. committee on high-speed calculating machines.

The first of the general sessions dealt with engineering and scientific applications of digital computers. A résumé of three of the papers that were presented for discussion at this session[1–8] is given here.

Power Station Engineering Problems[1]

In the design and operation of power systems, as in other fields of engineering, the use of digital computers can be most easily justified on those problems for whose solution existing methods are inadequate or are uneconomically time-consuming. Further applications become evident if existing techniques can be shown to be less accurate, less economic or less direct in formulation than those possible with the use of a high-speed digital machine.

The topics discussed reduce to matrix manipulation, the solution of linear equations and the determination of latent roots and vectors of a matrix. These linear algebra problems are particularly suited to solution on digital computers : indeed, they are of such frequent occurrence in many fields that interpretive routines exist so that programmes for a long sequence of matrix manipulations can be assembled in a few minutes.

Economic Load Dispatching.—One field in which the complexity of the analysis has precluded the achievement of more than an approximate solution is the economic operation of an interconnected system. The main data may comprise the characteristics of the power system, the specification of one or more particular load conditions and the different incremental costs of energy at the various generating points. In thermal stations the latter is determined mainly by the cost of fuel and can, in general, be expressed as a function of the power generated. The problem is to determine the optimum amount of power to be generated at each point, such that the overall cost of meeting the specified loads is a minimum. The complexity in the problem arises from the necessity to take proper account of the losses involved in transmitting the power from the generators to the loads. By contrast, in the conventional load-flow problem all generation is specified except at one station, which is constrained to supply the balance of the load plus all the system losses.

The economic loading problem would be in its simplest form if the transmission losses could be expressed as functions of the generated powers. No such expressions can be completely accurate, since the system currents are also functions of the reactive-power components. However, various investigators have developed methods by which approximate expressions can be derived. These are related to particular system loading conditions and somewhat arbitrary assumptions are necessary regarding the manner in which the individual loads vary with the total load.

The paper[1] assumes as an example that the losses can be represented by a function of the form

$$P_L=\sum_m\sum_n P_nB_{mn}P_m \quad . \quad . \quad . \quad (1)$$

and that the incremental cost of generation at the j^{th} power station is given by

$$dF_j/dP_j=a_jP_j+b_j \quad . \quad . \quad . \quad . \quad (2)$$

It is shown that, if B is the $n \times n$ matrix of B_{mn}'s, a is a diagonal matrix whose non-zero terms are $a_1\ a_2,\ a_3 \ldots, a_n$, I is a matrix whose every term is unity, b is a matrix whose i^{th} row consists of n elements b_i and P_G is the total power generated, the problem can be expressed as finding the real positive latent root and the corresponding vector of the matrix

$$\left(a+\frac{1}{P_G}b\right)^{-1}\left(2B-\frac{1}{P_G}I\right) \quad . \quad . \quad . \quad (3)$$

the latent root representing the incremental cost and the vector indicating the proportion of the demand to be met by each of the n stations.

Matrix manipulations of this type are particularly amenable to solution on electronic computers, and a powerful interpretive programme exists for "Deuce,"* by use of which the programme cards necessary to evaluate the expression (3) can be readily assembled, and the machine operation can be completed in a few minutes. The determination of latent roots is also an operation well suited to a digital computer, and the iterative method which has been used requires $0{\cdot}0052n^2$ seconds per iteration, where n is the number of stations in the system.

Modifications are required to the form of solution if certain stations are considered to be generating a specified amount of power, or if the incremental costs are represented by a number of linear relationships over various ranges of output.

In practice there are numerous additional considerations besides optimum economy which system operators must consider, perhaps the most important being provision for adequate security of supply.

The greatest incentives to employ more exact methods of scheduling generation arise on those systems in which large variations exist between generating costs and those in which transmission losses are proportionally largest. While various semi-automatic analogue computers have been constructed for use in this problem, the greater accuracy, flexibility and speed of digital machines should increase the possibility of more completely automatic performance of the required computations.

Load Curve Analysis.—A computational problem from a different field of power-system engineering is that of determining the shape of the load curves attributable to various individual classes of consumer, this information being of value in the formulation of tariffs and in system planning. On a large system a number of sub-stations will exist and, in general, the loads supplied from each of these will comprise the different consumer classes in various proportions. If a continuous record is available of the total demand at each such substation for a particular day, and if a quantity can be determined which characterises the individual consumer classes supplied from each substation, then, by regression analysis, the best average shape for the daily load curve for each class of consumer can be determined. The record for each day may be obtained by half-hourly "printometer" readings of the consumption at the substations, and the aggregate consumption over a fixed period of all consumers of one class supplied by one sub-station may be taken as the quantity characterising that type of consumer at that substation.

It is shown in the paper that the solution reduces to a sequence of matrix operations, and the required results can readily be derived on a digital computer. Specifically, if P_{it} is a measure of the outgoing power at the i^{th} substation at a time t, if A_{ij} is the energy consumption over a fixed period of all the consumers of the j^{th} type served by the i^{th} substation, and if a jt is a measure of the ordinate for time t for the j^{th} type of consumer, then the values $a\,jt$ are shown to be given by

$$a=[A'A]^{-1}\ A'P$$

where A, P and a are the matrices with elements A_{ij}, P_{it} and a_{jt}, respectively. As in the case of economic loading, the problem reduces to a series of routine matrix manipulations.

Three-Phase Circuit Analysis.—Well-known methods using mesh or nodal analysis are available for the solution of the current flow in a network resulting from the application of specified voltage or current sources. Unbalanced conditions in three-phase circuits are usually studied by means of symmetrical-component analysis ; provided that a certain symmetry exists between the phases, this enables the complication of mutual coupling terms to be avoided in the analysis, but at the expense of a double transformation to obtain the required phase quantities. A high-speed digital computer can be employed to solve large numbers of simultaneous equations for currents or voltages without restriction on any form of symmetry existing in the impedance matrix. Thus, three-phase problems involving unbalanced conditions can be expressed in terms of phase currents and voltages, and solutions can be obtained in a direct manner for the required quantities. When the usual assumptions apply regarding equality of mutual coupling between phases, the elements in the phase impedance matrix have a simple relationship to the sequence impedances ; an example in the paper gives the equations for a section of double-circuit three-phase transmission line.

Electric Traction Problems[2]

The calculation of train running times, given the power/speed characteristics of the locomotive, the resistance to motion of the train and the topography of the route, is carried out by most traction-equipment manufacturers and by many railway administrations. The results of these traction performance calculations are used to determine the most suitable design of equipment for carrying out a certain task, and the effect on fuel consumption of variations in time schedules and loadings.

The problem amounts to the solution of the equations of motion of the train

$$(1+\gamma)(M+m)v\ dv/ds=T-R-(M+m)g/n$$

and

$$ds/dt=v$$

where

v = Speed.
s = Distance.
Mg = Weight of locomotive.
mg = Weight of coaches.
T = Tractive effort.
R = Resistance to motion.
t = Time.
$1/n$ = Slope of gradient.
γ = Correction-term to take account of the rotating masses of the train.

* "Deuce" is a digital computer made by the English Electric Company, Ltd.

In addition, if fuel or energy consumption is required and an estimate made of motor heating, it is necessary to evaluate

$$W=\int w\,dt \text{ and } I_{rms}=\sqrt{\frac{\int I_M^2\,dt}{\tau}}$$

where

W = Rate of energy or fuel consumption.
I_M = Motor current.
τ = Total running time for journey plus a proportion of stopping time.

The tractive effort, resistance and motor current are functions of speed and are usually given in graphical form.

The solution of the problem is complicated by the facts that the gradient $1/n$ is not constant but varies along a given route, that the train must observe certain speed limits and that provision must be made for braking the train to a stop in stations, or to a reduced speed when entering speed restrictions. It is also important to know the effect on times and energy consumption of introducing a certain amount of coasting into the run. These calculations are extremely laborious if carried out by hand either by graphical or numerical methods, particularly if energy consumption and r.m.s. current is to be evaluated. An experienced man can determine speeds, times, energy consumption and r.m.s. current for about 5 miles of track in an hour, although this figure will vary according to the lengths of the gradients, the number of stations and speed restrictions.

To reduce the time and manpower spent on this work a number of special-purpose machines, some mechanical and some electrical, have been constructed for performing these computations and are used by various railway administrations (e.g. S.N.C.F. and Pennsylvania Railroad). These machines carry out traction-performance calculations in about one-tenth of the time required by manual methods.

With the arrival of the digital computer, however, it is now possible to reduce this time by a further factor of between 10 and 20, with a resultant saving in skilled manpower. A series of programmes have been prepared for the "Deuce" computer for carrying out such calculations, and the speeds of computation vary between 200 route-miles per hour for a d.c. electric suburban train with frequent stops to 2000 route-miles per hour for diesel-electric main line train.

A typical calculation is carried out in three main stages. First the lengths and slopes of each gradient, the position and radius of curves, the position and value of speed restrictions and the position of stations, are punched on cards in decimal form. The machine is then used to calculate the gradient and curve resistance and to punch these values and other gradient and speed restriction data in binary form. This information is then available for use in any calculations which may be carried out for this route.

The second stage deals with the power/speed characteristics of the locomotive and the resistance of the rolling stock. Although no facility exists for reading graphical data into the "Deuce," a programme for fitting algebraic-polynomial graphs is used for fitting polynomials to the tractive effort, train-resistance and motor-current curves. The time taken for the machine to calculate tractive effort for a given speed (equivalent to a man reading the appropriate value from a graph) is less than 20 milliseconds. The coefficients of these polynomials, therefore, give all the information required concerning the power/speed characteristics of the locomotive and the resistance of the rolling stock, and they are available for further calculations concerning this equipment.

In the final stage of the computations the main programme is read into the machine, followed by the train performance data, the gradient resistance and speed restrictions. The machine will then calculate the speed and time at each point of the journey by solving the equations of motion by a step-by-step process. It will also accumulate a running total of energy consumption, and $\Sigma I_M^2\,dt$, from which r.m.s. current may be derived. At each step the machine will check that the speed is not higher than the local speed restriction and that the train has not yet reached the point at which the brakes are to be applied to reduce speed to the next speed restriction. When this point is reached the machine calculates the time taken to brake to the next restriction and carries on the calculation from there. When a station is reached the machine punches out a card showing the distance travelled, the time taken, the energy consumption and the r.m.s. current for the previous station-to-station section. If the calculation of the effect of coasting is required, signals can be given to the machine by means of a set of switches which indicate the points on the line at which the train commences coasting.

Many other important calculations stem from these basic ones concerning the operation of trains. Energy or fuel consumption of an electric or diesel-electric locomotive is much reduced when a certain amount of coasting is introduced into a run. By hand methods it is an extremely lengthy business to investigate the effect on fuel consumption of different methods of operation and loading, but with a high-speed digital machine such investigations can be carried out readily.

When designing a new electrification scheme an estimate must be made of the load on substations, so that the size and required performance of the plant can be established. These calculations, based on the results of speed/time computations and the traffic density of the system, are extremely laborious by hand methods and much saving in time and labour could be made by performing them on a digital machine. Other applications to traction engineering in which a digital computer may be of great use are stress problems arising in the design of overhead structures and bridges and the study of rectifier harmonics.

Solution of Electric Circuit Problems Involving Switching Operations[8]

The analysis of electric circuits by matrix methods is well-established as a means for obtaining differential equations relating the electrical quantities in a circuit with the impedance properties of the circuit. The equations for circuits containing linear elements can be expressed as simultaneous, linear first-order differential equations with constant coefficients. A "Deuce" programme for solving such equations by a step-by-step method has been evolved, and many switching problems are amenable to solution using this programme. For a problem involving a single switching operation the procedure is to establish the equations for the circuit configuration after the switching operation and to solve these equations from known initial conditions for a suitable duration. A problem involving a number of sequential switching operations can be dealt with as a series of single switching problems, the final conditions for one problem providing the initial conditions for the subsequent problem. In general, the equations for each part of the problem are different and the procedure becomes tedious if the number of switching operations is large, as is the case with rectifier problems.

Rectifying elements can be regarded as switches whose opening and closing are either partly or entirely dependent on currents and voltages. The configuration of a circuit containing such elements will change as the elements are ignited and extinguished. The equations for any configuration can be derived from those of the complete circuit. For each configuration it is necessary to know the currents in the conducting elements and the voltages across the non-conducting elements in order to detect a further change of configuration.

Certain well-known kinds of power-rectifier installation can be represented by a small number of equations describing the complete circuit. For some installations of this kind there is a large demand for solutions to problems, and it has been found desirable to make a special programme for each type. Sets of equations for all possible circuit configurations are stored, the set appropriate to the configuration is selected and solved and the solution is examined to detect an ignition or an extinction. Two such programmes have been made for calculating, respectively, fault conditions subsequent to a backfire in a three-phase rectifier and normal operating conditions of a bi-phase rectifier.

The backfire programme has two parts: the first reads in the circuit parameters, the initial values of current and time and a parameter to fix the size of step to be taken in finding the solution; the second checks when a current becomes zero or negative and registers that the corresponding element is now non-conducting; it also calculates the voltages across the non-conducting elements and registers when they ignite. It then selects the appropriate set of differential equations and solves them by a two-stage Runge-Kutta process over one step of the specified size and repeats this sequence indefinitely. The position of an input key on the computer determines whether the values of the currents are punched out at every step or only at ignitions, extinctions or current maxima or minima.

The bi-phase programme is a modified version of the backfire programme, and has been used extensively in calculating the harmonics in the input and output currents of bi-phase rectifier installations. It was necessary, in each example, to find steady-state conditions; this was done by allowing the calculation to continue until two values of a current at corresponding points in successive cycles were found to be equal. The resulting solutions for the currents were analysed into harmonic components, using an existing programme.

The techniques employed in making the special programmes could be applied to circuits for which the number of equations and the number of rectifying elements were large. The procedure is made unmanageable, however, by the labour involved in deriving algebraically the equations for each group of conducting anodes and by the necessity to store in the computer the coefficients of these equations, there being 2^n possible groups of conducting elements for an n-element rectifier installation. In addition, there are many rectifier circuits which are of interest but for which the demand for examples would be insufficient to justify the making of special programmes. For these reasons it was decided to aim at formulating a method which could be incorporated into a general rectifier programme.

An iterative method has been developed but has not yet been programmed. The basis of the method is that the opening of a branch of a circuit is simulated by inserting into that branch a large inductance in series with a voltage source. In effect, before each step of the solution the voltages across the inserted inductances are calculated and each value is added to that of the voltage source associated with the same branch. The process is repeated until the rates of change of the currents in the open-circuited branches are acceptably small, at which stage a step of the solution is taken. A main characteristic of the method is a procedure for modifying the inverse of an inductance matrix to take account of the changing of the inductance of any branch of the circuit. The iterative procedure converges on a rigorous solution provided that the latent-roots of the inductance matrix are all positive—which is always the case for physically realisable circuits. The general programme will use the two-stage Runge-Kutta process for solving the equations formed by this method and will interpolate to find times of ignition and extinction.

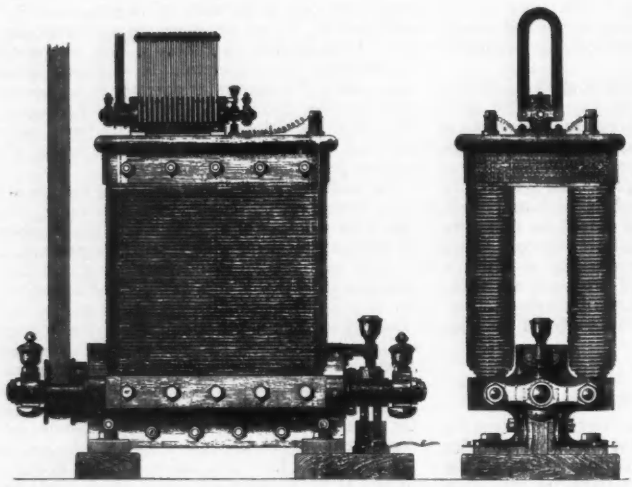
The extensive use which has been made of the three-phase and bi-phase programmes has indicated their value for providing solutions at short notice over a long period of time. It is anticipated that the existence of a general programme will make worth while the solving of problems which occur too infrequently to justify the making of special programmes and which otherwise would not be tackled with such a degree of rigour.

References

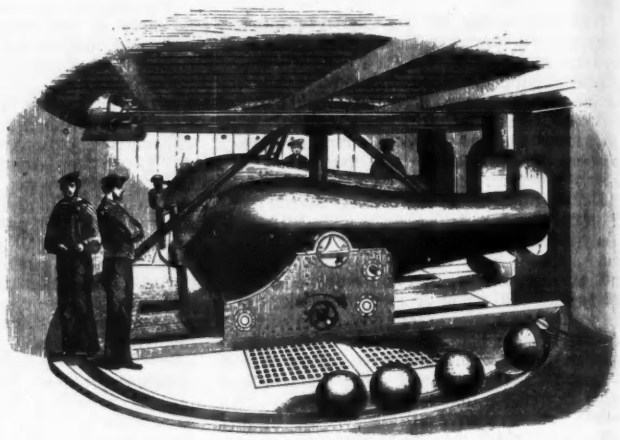
[1] C. Robinson and D. H. Tompsett, "Power System Engineering Problems with Reference to the Use of Digital Computers."
[2] A. Gilmour, "The Application of Digital Computers to Electric Traction Problems."
[3] S. J. M. Denison and D. G. Taylor, "The Use of Digital Computers in Solving Electric Circuit Problems Involving Switching Operations."
[4] G. G. Alway, "The Use of the Pilot 'Ace' for Testing a New Design of Proton Synchrotron."
[5] W. D. Worthy, M.A., A.M.I.E.E., "The Use of Interpretation Routines on a General-Purpose Digital Computer for the Design of Linear and Non-Linear Control Systems."
[6] B. Birtwistle, B.Sc., and Miss Beryl M. Dent, M.Sc., "The Digital Computer as an Aid to the Electrical Design Engineer."
[7] J. V. Oldfield, B.Sc. (Eng.), "Contribution on Transformer Design with Digital Computers."
[8] J. M. Bennett, "Digital Computers and the Load Flow Problem."

Engravings of 1866

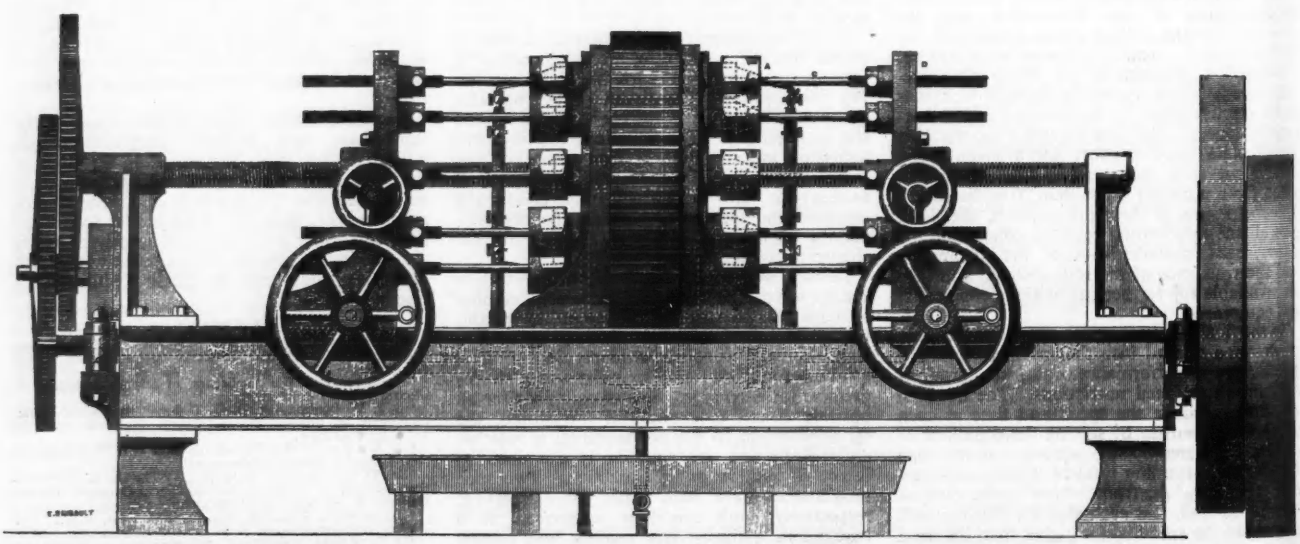
In our issue of April 13, 1866, we stated that we were "inclined to lay great value on photographs of boiler explosions, for useful lessons for the avoidance of similar disasters can be got from their study." The upper engraving (right) illustrates the effects of a boiler explosion which occurred, in June, 1865, at Bass and Co.'s brewery, Burton-on-Trent. Our account says "we have termed it an explosion, but it was, more properly speaking, a collapse of the internally-fired flues of a Cornish boiler." The shell was 32ft long, 7ft inside diameter, and its flue was 4ft in the internal furnace and flue tube. Though the safety valves "were loaded to a pressure of at least 50 lb and upwards, the thickness of metal of the flue was only seven-sixteenths of an inch." According to our report, "it was stated by a scientific witness at the inquest that, even with this size and thickness of metal, the flue measured 4ft vertically and 3ft in a horizontal direction! This was, however, a mistake, as it was only about 1in or 2in oval. The whole boiler was torn off its seating, and launched about 7ft or 8ft."



The engraving above illustrates a "7in electro-magnetic machine" constructed by Wilde and Co for the Commissioners of Northern Lighthouses, and described in our issue of June 8, 1866. That description comments that "the brilliant discovery made by Mr. Wilde of a new and powerful method of inducing currents of electricity for the production of the electric light has been promptly taken up by the Government." The description then records that "the armature of the 7in machine is driven at 1800 r.p.m. by means of a strap from the same shaft as is the magneto-electric machine, and the journals and commutators of both armatures are furnished with suitable lubricating apparatus for maintaining a constant supply of oil to the rubbing surfaces. The total weight of the machine complete is a little more than 1½ tons."



Our issue of May 4, 1866, included some engravings of the United States monitor "Dictator," which was designed by Captain John Ericsson. The engraving (right) shows the interior of the turret, the top of which was formed of perforated iron plates 1in thick. The turret, and with it the 15in guns, was "turned round by means of gearing driven by a pair of donkey engines."



Above, there is illustrated a drilling machine installed at the works, in City Road, London, of the Cold-Drawn Steel Tube Company, and described in our issue of March 16, 1866. The description says .. "ten ingots are drilled at one time. The machine only requires the attendance of one man and a boy, and can turn out from ten to twenty ingots, each producing from 20ft to 40ft of tubing, according to thickness, in ten hours."

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

"THE MODEL TECHNIQUE"

SIR,—I should like to bring to your attention a technique I have evolved which may help to promote the efficient interchange of information. A difficulty facing any person with a question in mind lies in what might be called the Unknown Possibility. Some one, far removed in distance or time, may have invented or discovered something of great potential interest, but about which one has not heard. One would not know in what terms to frame a question, let alone where to seek an answer, and one can only hope to come across an account in the literature by chance, or to see the relevant advertisement, or to be present at the right conversation.

The proposed solution—which may be called the "Model Technique"—is that people, who share a common interest or aim, pool their ideas and knowledge at a single agreed location. This location, together with the carefully assessed collection of knowledge and literature, would be called a "Model."

There appear to be two advantages offered by the technique :—

(*a*) Since the information relating to a given topic or aim would be gathered at the "Model" by many people, the information could be regarded as reasonably comprehensive and up-to-date. Deficiencies would be pointed out by the visitors to the "Model," so that either the visitors improve the "Model," or the "Model" teaches the visitors.

(*b*) Provided that means are established to enable the potential user to know where the relevant "Model" lies, the knowledge is disseminated in a very efficient manner.

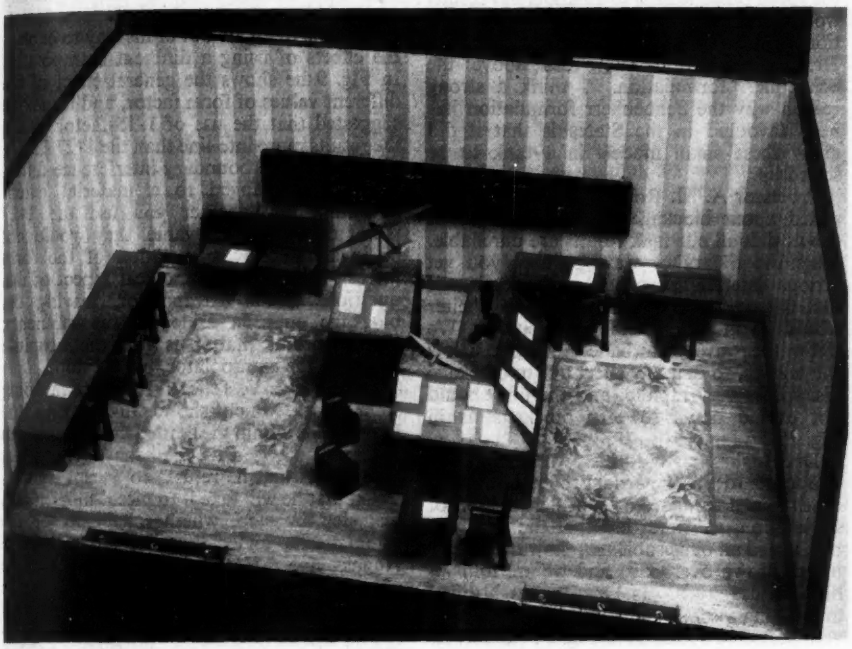
The illustration shows a proposed layout for a "Model," which relates—quite arbitrarily—to the problems of sail-plane construction. The central cabinets would contain information on construction techniques, materials, design data, and so on. This information is filed in the normal way. Particularly interesting information is displayed on the inclined portions of the cabinets, in order to attract immediate attention. Samples of materials adjoin the display cabinets and day-to-day changes of information appear on the blackboard.

The technique has been tested in a very rudimentary way ; it appears to offer no difficulties and has been helpful.

This letter is published by permission of the Chief Scientist, Ministry of Supply.

PETER H. H. BISHOP

Farnborough,
April 4th.



A model of a "Model"

BOYS AND CAREERS

SIR,—As a member of the organisation which, through its Vocational Guidance Clinic, is closely concerned with boys and careers, I write to add my "amen" to your very good leader. Where we think it appropriate, we do not hesitate to bring to the notice of both parents and boys "the rewards and opportunities that technology offers," extraordinarily diverse though these may be.

Your statement about the boy who comes from a comparatively uncultured home interests me greatly, however, since it recognises a vocational problem which is, I think, peculiar to our times. The very opportunities referred to were mostly non-existent for the older generation from this kind of background such that when the young person of to-day is later led by these opportunities into situations and problems unknown to his parents, and hence not understood or appreciated by them, he frequently finds himself unsupported in lonely surroundings or bewildering positions. It is then that this disparity of opportunity may lead to a gulf between parents and boys, and one becomes increasingly aware of the youngster's cry from the heart—of the kind : "my parents have shown indifference to my progress."

W. ISBISTER

National Institute of Industrial Psychology,
London, W.1.
April 10th.

Literature

The History and Development of Cycles. Part I. By C. F. CAUNTER. H.M. Stationery Office. Price 4s.

THIS part of the history of cycles, as illustrated by the collection in the Science Museum, is a historical survey. As such it is essentially factual, and even this chronology is full of interest. The idea of manual, or rather, pedal, propulsion had been incorporated in various machines before the 1819 quadricycle of the Reverend Edmund Cartwright, but was first applied to a two-wheeler by Kirkpatrick Macmillan in 1839. The author considers the first successful bicycle to have been the crank-propelled front-wheel-drive Michaux velocipède of 1863, and it is interesting to note that in 1868 a Michaux machine was fitted with a Peneaux steam power unit to make the first motor-cycle. The emergence and decline of monocycles, dicycles, tricycles, quadricycles, and the pentacycle is discussed. The origin of the safety bicycle is credited to H. J. Lawson, in 1873, and the rapid development through J. K. Starley's Rover designs to reach the currently accepted form early in the twentieth century is traced. Recent refinements are described and hope is held out for the cross-frame design. One chapter is devoted to auxiliary engines for pedal cycles, and mentions some of the cycle-motors in use to-day. The scope of this book does not allow any reference to underlying principles; the reasons for the protracted drive for light weight and even for the basic proportions of the diamond frame are left for a later publication. Although the illustrations are arranged with little semblance of order, they add greatly to the value of the volume, and two engravings offset the numerous photographs of cycles statuesque, though machines such as the rakish Singer "Xtraordinary" appear imbued with movement even on the page.

Books Received

Chromium-Nickel Austenitic Steels. By F. H. Keating. Butterworths Scientific Publications, 88, Kingsway, London, W.C.2. Price 25s.

Micro-Indentation Hardness Testing. By B. W. Mott. Butterworths Scientific Publications, 88, Kingsway, London, W.C.2. Price 42s.

A.C. Generators and Motors. By Philip Kemp and W. H. Date. Sir Isaac Pitman and Sons, Ltd., 39, Parker Street, London, W.C.2. Price 6s. 6d.

Color Television Standards. By Donald G. Fink. McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 64s.

Peaceful Uses of Atomic Energy. Volume III. *Power Reactors.* United Nations Publication, Sales and Circulation Section, Department of Public Information, United Nations, New York, U.S.A. Price 54s.

Institution of Naval Architects

ANNUAL SPRING MEETING

No. III—(*Continued from page 325, April 13th*)

ON Wednesday afternoon the second paper presented was :

VISCOUS AND INTERFERENCE EFFECTS DEDUCED FROM N.S.M.B. AND N.P.L. "VICTORY" MODEL TESTS

By G. HUGHES, D.Sc., Ph.D.

SYNOPSIS

The "Victory" ship model tests carried out by the Netherlands Ship Model Basin have been supplemented by a series of similar tests at the National Physical Laboratory. The combined results have been analysed in relation to assumed viscous formulations and the tank boundary interference effects required to provide a balance have been deduced. It is shown that the interference effects which correspond to the viscous formulation proposed by the author from earlier work are consistent and reasonable, but further work of a similar kind is required to enable the viscous and interference effects to be separated out more accurately.

DISCUSSION

Dr. Hughes, after presenting the paper, said : This work is being continued. We have already got together a lot of other data and are continuing to work on other forms. I suggest it is a little unwise at this stage to draw too firm conclusions from the results in the paper. We may find that the interference at low Froude numbers is linear with blockage ; but we have evidence that there is a partial linearity if the Froude number is increased beyond the range of these particular tests. This may prove to be a bottom effect rather than a pure blockage effect.

Professor G. Aertssen : The conclusions of the Dutch scientists on their "Victory" model work were not pertinent enough to permit a generally admitted formula for three-dimensional extrapolation of skin friction to be established. It was a good scheme for Dr. Hughes to complete this "Victory" programme by similar tests at the N.P.L. and to compare the results from both tanks in a re-analysis of the data. The resistances are corrected for the drag of the stimulators and the effect of laminar flow, and the corrected results are then considered in relation to the Hughes viscous formulation in order to deduce tank boundary interference. That this interference effect is linear and increases with speed in a normal way is certainly an argument on which to base a viscous formulation. But the weakness of the argument is that the intensity of this interference is not known in another way. The interference values given in the paper are surprisingly high, and more evidence on this high level of boundary interference is desired.

It is likely that a long-established interest in a given formulation of viscous resistance will vanish from the moment the tank is able to make more accurate corrections on the test results. Why does he say so little of the model boat at Wageningen ? The scale of this model is so large that the results may not be ignored. The Dutch scientists say the boat was hydraulically smooth, but Figs. 8, 9 and 10 of the paper give a substantial roughness. The "Tervaete" would give a much higher roughness allowance, but the ship was eight years old and not better than commercially clean during the best of her trials.

The measurement of local resistance in large ships is certainly useful for the establishment of the extrapolator. Mobile plates in the hull did not give much information ; why should not advantage be taken of pitot traverses for the establishment of local frictional resistance and for the description of roughness?

Mr. P. R. Crewe : Our organisation is now constructing a second tank ; it is 12ft wide and has 6ft depth of water. I mention this because we have to calibrate our own tank, and in order to do that we have built two "Victory" ship models, to 1/50th and 1/80th scale. We have finished the models very carefully with a black plastic, and the purport of it is to use chemical indicators to determine laminar flow.

In order to make some comparison with the results reported in this paper we have taken Dr. Hughes' 1/32 scale data as the basis, and our tentative finding is that in the speed range from 3 to 13 knots our results would agree with the Schoenherr formulation ; in that range for this very small model Dr. Hughes' formulation lies above the Schoenherr formulation. I think a strong reason why the Schoenherr formulation has been favoured in the States is that it did allow these small models in a tank to be scaled up.

Professor A. M. Robb : If what has been stated about blockage resistance is true, it shows that all our tank results are unreliable. Take the theory of waves, where you get serious interference effects with depth. If that is true, the submarine going for shelter would be in a very difficult position. We know the wave disturbance dies out below the surface, so that any effect due to blockage disappears very rapidly, and the line should not extend down to zero blockage as in Fig. 25.

Dr. Hughes has used his own friction line as a standard; has he a right to base anything on that as a standard ? On the question of stimulation, we were told that the trip wire had solved all our problems ; now that seems to be thrown overboard and we are told we have to use studs. Is Dr. Hughes justified in plotting viscous differentials from curves with scattered spots, as in Fig. 3? Surely he should join up every spot.

I have a feeling that this Institution is being used as a guinea pig ; he is trying out this line in preparation for next year's international conference. The Skin Friction Committee was enjoined to produce an agreed line. We have refused to accept the Schoenherr line ; it is founded on a very shaky basis, but I should hate a British representative to come along and say that this line rests on any sounder basis.

Dr. J. F. Allan : I feel that the previous speaker is unfair in suggesting that Dr. Hughes, or the N.P.L., are using this Institution as a guinea pig. I think Dr. Hughes, and particularly the N.P.L., are to be congratulated on putting this information forward, so that it is available for consideration. The International Skin Friction Committee of the Conference was enjoined to study this matter urgently and to bring forward proposals to the next conference ; it is because of that that this work has been pressed on. This is a series of experiments on the "Victory" ship models, and several other series of experiments have been carried out on different forms, with a view to our having as much accurate data as possible to study in connection with this matter.

The question of accuracy is of extreme importance, and great care was taken to ensure the highest possible degree of accuracy in these experiments. The serious divergencies between the results in the diagrams are attributed by the author to laminar flow areas and boundary effects. The argument is carefully developed, but it is pertinent to know that there is no absolute proof of the extent of the laminar areas ; that may be considered a point of criticism against the data. For instance, in Figs. 1 and 2 there is a noticeable difference in the character of the resistance curves of the large Dutch model as compared with those of the other models.

This work was directed to the study of extrapolation, but in the course of the study we have found that laminar flow and boundary effects are of importance. To some extent we have become side-tracked from the main purpose, and the paper seems to concentrate more on the boundary effect than on the question of extrapolating.

In the section dealing with the analysis of corrected results I feel that Dr. Hughes has been unjustly taken to task for basing most of his analyses on his 1·27 form factor, because he has gone out of his way to explain the effects of using a different extrapolator. In Fig. 9 he shows the general effect of the different values of form factor, and it may be suggested that the use of 1·15 factor brings the results more into line than the 1·27 factor.

Although the boundary interference differentials are changed to a material extent depending on whether you use the 1·27 factor or some other value, they would not be invalidated by a variation of the form factor. There is one practical aspect of this question of the extrapolator, leaving the blockage question aside for the moment; the important matter is not the absolute height of the extrapolator, but its slope.

Professor E. V. Telfer : I have been doing some work which shows that, using the Hughes line within the limited data, there is no difference between us. All that Dr. Hughes is saying is that he refuses to accept Telfer's work, that he will take it to pieces himself and see, step by step, whether he can get the same results under the pseudonym of the Hughes line. He does not prove that the Hughes line is any more correct than the extrapolator.

So far as his experimental work is concerned, I have no fault to find ; he has rendered fine service by repeating the N.S.M.B. results, and I congratulate him, even if I criticise the accuracy of the data. These results are capable of greater accuracy, particularly for the smaller models.

The spring meeting continued on Thursday, March 22nd, with Sir Charles S. Lillicrap in the chair and with the reading of :—

THE BRITTLE FRACTURE STRENGTHS OF WELDED STEEL PLATES

By A. A. WELLS, B.Sc. (Eng.), Ph.D.

SYNOPSIS

An account is given of a series of tensile tests on wide mild steel plates of 1in thickness, where the plates contained central, notched butt welds parallel to the direction of pull. The notches consisted of fine, shallow saw cuts made in the plate edges prepared for welding, and were intended to simulate weld flaws. The tests were conducted within the temperature range ±15 deg. Cent., which was below the fracture appearance transition temperature of the parent material.

Above 4 deg. Cent., the plates sustained yield point average static tensile stresses before brittle fractures occurred. Below 4 deg. Cent. brittle fractures across the weld residual stress zones started from the sawcuts, either spontaneously after welding, or with small external loads. With continued loading, complete fractures were obtained only after general yield of the remaining plate cross-sections. At 4 deg. Cent., a single stage fracture was produced at half yield point stress. In further tests between ±15 deg. Cent. no residual stress zone fractures could be produced at less than yield point stresses in welded

plates previously stress relieved by stretching at 40 deg. Cent.

Considerable importance is attached to the critical temperature, at which alone complete fracture could be obtained at half yield point stress. The Charpy V-notch energy of 7ft-lb at this temperature matches the energy range identified by Williams for casualties in American welded ships. Evidence is presented to show that the behaviour in these tests may be explained mainly in terms of the mechanical effects of weld shrinkage and residual stresses, and metallurgical damage over the narrow weld-hardened zone.

Dr. R. Weck : With reference to his Fig. 10, the author states that " The peak tensile stress of 23·5 tons per square inch along the weld is indicative of metallurgical effects other than simple shrinkage during the cooling cycle." Is it not possible that there are such metallurgical effects that they might be superimposed on the effects of residual stresses or that might have an equally serious effect on the initiation of brittle fracture ?

It is important to know whether the strain energy for the propagation of a crack for the plate material is the same for the weld material and for the material in the affected zone.

After overloading or prestraining one can, as the author says, relieve the residual stresses and therefore prevent the initiation of the short fractures which propagate under relatively low external loads. I would have thought that if a notched plate were extended at above the transition temperature at a stress at about the yield point, and then unloaded, on unloading there would be residual compressive stresses at the end of the notch, and that it is a consequence of these residual compressive stresses that fracture does not initiate at a low stress when the stress is repeated at below the transition temperature.

Reference is made to the conclusion that the residual stresses are responsible for supporting propagation of the primary fractures, so that without them low load fractures of the calamity type are not possible in tests of the kind described. The author states : " This conclusion cannot, however, be lifted from its context and applied to all structural conditions, since some exist where there are high strain energy release rates at quite low stress levels. . . ." This sentence is very important.

Mr. J. Hodgson : The goal of this investigation is to match a laboratory test with casualty behaviour, and therefore it is fundamentally important to examine carefully how the conditions of the test compare with service conditions and how the results can be correlated with those derived from investigations into actual casualties.

From a study of the service history of fractures it can be postulated that from an initial defect a small primary natural crack develops and extends into the parent plate. The time in which this occurs may be long or it may be short, depending on the fluctuating cycles of stress, temperature and weather in relation to the quality of the steel. Casualty results show that serious fractures have occurred without previous warning after long periods, despite the fact that the ships have been for some years on the same service. Serious fractures have occurred at sea at temperatures from about minus 5 deg. to plus 20 deg. Cent. Since fatigue is never present, I have wondered whether there is some factor of time endurance applicable to the steel. There is also the possibility of strain ageing of the material over varying periods of time.

Another service factor is shock, and in recent complete failures of post-war ships shock has been definitely reported.

Would the results of the investigation have been the same if the strain rate had been varied, or if the testpieces had been given a blow with a hammer when at a very low stress, or if some time factor had been introduced into the experiments?

This paper marks the start of an important investigation, but it does not tell much about the question of how tough a plate should be to meet service conditions successfully over a long period. Investigations should be based on a realistic appreciation of service conditions and the significant factors which emerge from many failures. From analyses of many tests on casualty steel we have been unable to find any common or reliable datum on a Charpy energy curve which would correlate with service fractures for all steels. But we have found a promising correlation between fracture appearance and service casualties, as a casualty material exhibits at the casualty temperature predominantly crystalline fracture.

It might be inferred from the paper that, provided you stress-relieve the seams in a welded ship you could afford to use a fairly brittle steel. Any such proposal would be wrong, because you take out the residual stress in the seam and you have stored energy in other parts of the ship. Local stress relieving would not remove initial weld cracks or flaws ; it might well aggravate them. With all reasonable precautions and supervision no shipbuilder could guarantee the absence of incipient weld cracks, and steel makers could not guarantee steel entirely free from small internal defects which may be potential sources of fracture under service conditions.

We must admit that in the best of steel ships there will be some small initial weld cracks which may develop into primary natural cracks in the base metal, and therefore the steel, as far as possible, should be able to tolerate this unavoidable condition.

Mr. R. H. Richards : In the author's Fig. 8 there are few spots in the critical zone and it seems to me that the lines have been drawn in on slender evidence. For example, specimen *D* was tested at a temperature only 2 deg. higher than the " calamity " temperature, but the results do not fit the curves drawn, and because of this I would have liked to have seen the results from specimen *H* confirmed by a further test at or close to the " calamity " temperature of 5 deg. Cent.

It is not easy to follow some of the energy arguments, for there are several experimental and theoretical steps which lead finally to Fig. 13, these steps being in some cases based on measurements with artificial cracks statically opened.

Dr. L. E. Benson : I do not believe that 4 deg. Cent. is in any scientific sense a critical temperature, and I deplore the term " calamity temperature." Whilst Fig. 8 demonstrates the main point Dr. Wells has to make, it is not the best way of presenting the evidence to show what is really happening. However, something can be done in this direction if we make use of the residual stress distribution shown in Fig. 10 to estimate the total stresses operating at the start and finish of the cracks, instead of just the applied stress as shown in Fig. 8. We must also differentiate between cracks starting at pre-existing sharp cracks and cracks starting at machined notches which are comparatively blunt. Using only data given in the paper, I show in a diagram the result of doing this. At the bottom terminal stresses for the primary cracks indicate the approximate position of the curve of minimum stress to maintain a running crack, while the top half of my graph gives stress/temperature curves to initiate cracks. Two curves have to be drawn, one for cracks starting at cracks, and one for cracks starting at relatively blunt machined notches. The Tipper tests, which are brittle fractures starting at machined notches, fit and their inclusion is justified. The lie of the points strongly suggests a transition in the curve in the range —1 deg. to 4 deg. Cent., and more points in this region, including some Tipper tests, should be provided to confirm or refute the correctness of this conception.

Fig. 8 shows that any criticality in the region of point *H* depends on the transition in the region of —1 deg. to 4 deg. Cent. This temperature is governed by the characteristics of the steel, the notch sharpness and the amount the notch projects into the residual stress field surrounding the weld.

Point *H* in Fig. 8 is the only secondary, or complete, fracture to start at a saw cut. Had more specimens been pulled at higher temperatures, those with cracks starting from saw cuts would have given secondary failures at the same level of applied stress as fracture *H*—about 9 tons per square inch. Those with primary cracks would have continued to fail at about 15 tons per square inch, and there might have been some in between giving a band of points to the right of 4 deg. Cent. To the left of this temperature, saw cuts gave rise to cracks at lower applied stresses, so that the cracks were arrested on running into the low residual stress field and became primary cracks. Below the —1 deg. to 4 deg. Cent. transition, therefore, we are left with secondary cracks starting only from primary cracks, the applied stress being relatively high because the residual stress is there low and because a primary crack, once stopped, requires a stress in the region of the yield point to start it again. Thus we have the surprising result that under certain conditions the applied stress for catastrophic failure can be lower at temperatures above the " transition " temperature than at temperatures below it.

From my diagram the question arises, is there or is there not a notch sharpness factor for the initiation of brittle cracks? There is no question about there being a notch sharpness effect at temperatures where the fracture changes in character from brittle to tough.

Mr. T. S. Robertson : I ask for some reliable references to the work of the stress picture ahead of the crack. There is a lot of work going on in America in which they are using strain gauges and measuring the stress field ahead of the apparent crack on the surface, but it is becoming more and more evident that the crack tunnels along under the surface a long way ahead of the appearance either of yield or of the break of surface as the crack comes through it.

There is a general tendency to regard the brittleness of a material as constant. What is the effect of roll strain on the material ? I believe it is brittleness.

Mr. W. D. Rankin : The concept of a " calamity " temperature is novel and requires further investigation to substantiate its relation to service behaviour.

Generally, in ships or other welded structures which have failed, the drop in temperature so often associated with casualties occurs while the structure is under its working stress. This working stress may not be static, but may be fluctuating considerably about its mean. In the Wells test the sequence of applying the load and cooling is reversed in relation to that occurring in most service casualties. However, this is not always so, and it remains to be seen whether there is indeed a difference in the results obtained by cooling before applying the load and those obtained in applying the stress before cooling.

Mathematical analysis of the results shows

High-Speed Five-Stand Tandem Cold Strip Mill

No. II—(*Concluded from page* 343, *April* 13*th*)

A new five-stand tandem cold strip mill installed at the Ebbw Vale works of Richard Thomas and Baldwins, Ltd., is designed to operate at a maximum speed of 5000 *feet per minute. It is intended for reducing hot rolled steel strip down to tinplate gauge up to* 38*in wide. The ingoing gauge of strip is up to* 0·140*in if required, the minimum outgoing gauge being* 0·006*in. The electrical drives are described here.*

As stated in the preceding part of this article the English Electric motors coupled to the mill have the following ratings :

	Output h.p.	Speed range r.p.m.	Strip speed f.p.m.
Stand 1	1750	90/255	495/1400
Stand 2	3500	125/304	687/1670
Stand 3	3500	200/445	1100/2445
Stand 4	4000	350/645	1925/3545
Stand 5	5500	500/910	2750/5000
Coiler	900	233/1000	5000

Stand 1 is driven by a single unit motor, stands 2, 3, and 4 and the coiler by double-unit motors, and stand 5 by a triple-unit motor, the armatures being interchangeable within a multi-armature motor.

Two 11kV, 9000 h.p., 600 r.p.m., synchronous motor-generator sets supply the main drive motors at a maximum of 620V d.c. through short copper runs, the ten main generators being identical and interchangeable machines. Each of the 9000 h.p. synchronous motors is arranged for reactor starting although they can be direct-on-line started if necessary ; automatic excitation control is provided.

A general view of part of the motor-room is shown in Fig. 3. All the main drive motors and generators are force-ventilated on a re-circulatory system except for the commutators which are naturally ventilated, allowing easy access for inspection and maintenance. The bearings of these machines, besides having standard oil rings, are connected to two separate flood lubricating systems, each with its own standby unit. One main and three control exciter sets are installed in the motor-room, these machines having end-shield ball and roller bearings. The highly sensitive controls for the complete equipment depend on the operation of the control exciters and magnetic amplifiers.

Fig. 3—The motor-room of the five-stand tandem cold reduction mill. The drive to the mill is on the left

Control Equipment

A separate control room contains the supervisory board which sets up the electrical equipment for running and provides instrumentation and extensive alarm facilities. Behind this supervisory board is a corridor-type control board having cubicle-mounted magnetic amplifiers on one side and flat-back contactor gear on the other side. The magnetic amplifiers are mounted on withdrawable chassis to facilitate maintenance. Many of the control and main circuits are monitored on a panel on the contactor board thus giving instant indication of the condition of such circuits, an essential requirement if the mill "down-time" is to be kept to a minimum.

The control room also houses the mill master control rheostat, which is motor-operated and has contact-making rollers running over vertical stacks of contacts connected to the resistances. This construction enables a considerable number of rheostats to be easily ganged together to control many quantities sumultaneously. The mill master control rheostat is remotely controlled from the stand control cabinets.

Installed in the basement of the motor-room are the air circuit breakers in the main generator-motor copper runs to provide isolation and dynamic braking of the motors. Alongside, near the main motor foundation blocks are the motorised rheostats, which are of similar construction to the unit described above, for the individual speed setting of the stand and coiler motors.

Mill Operation

Referring to the mill motor speeds it will be observed that they give rise to a "speed cone", which allows a large range of rolling schedules to be accommodated by individual stand settings. This "speed cone" normally corresponds to the shunt field ranges of the stand motors, but it is widened by further reduction of speed of each individual stand by generator voltage.

The procedure followed in setting up a mill of this kind for a particular rolling programme is first to determine the gauge reduction to be made in each stand and relate it to the stand speeds, having regard to the available speed in the "speed cone." The motor shunt fields and the mill screws are then set to the estimated positions and the first coil can be entered into the mill at the low threading speed. The load on each stand motor and the interstand strip tensions must then be checked against the estimated values and the motor fields and mill screws adjusted accordingly.

To reduce strip wastage to a minimum during the setting up of this kind of mill it is essential that the "thread" speed be as low as possible. In practice the control scheme for this mill allows the thread speed on to the coiler to be adjustable over a range of 120ft per minute to 400ft per minute. With the strips successfully threaded the mill must be accelerated to the programme top speed as quickly as possible to reduce the "off-gauge" material to a minimum.

In any high-speed tandem mill changes in interstand tension and gauge with changes in speed are known to be inherent in the nature of the operation. This "speed effect" is thought to be due to variation in roll and bearing lubrication, in roll deformation and in the speed of roll deformation between high and low speed. The effect is very apparent on high-speed tandem mills rolling down to thin gauges and has the same effect as would be obtained by increasing screw pressure with increasing speed. The result is a decrease in output gauge with increasing speed and vice versa. A drive can theoretically be made to maintain the speed relationship between stands at all strip speeds and thus maintain gauge, but "speed effect" would then result in increasing interstand tensions on deceleration. On a wide-speed-range mill, rolling thin material, this increased tension would result in strip breakage. To avoid breakage, provision has been made on the electrical drive of this mill for a large degree of flexibility in adjustment of motor load-speed droop or "regulation," both as fixed amounts and as amounts depending automatically on speed. In this way the whole drive is given a characteristic such that the undesirable results of the inherent "speed effect" are minimised.

The requirements of the coiler drive are no different to other mills of this kind. The strip tension has to be maintained at a controlled steady value as the coil builds up on the drum. There are two independent servo systems for achieving this control. A voltage control of the coiler motor acts on the motor field to keep the motor voltage proportional to strip speed independently of the coil build-up. A current control of the motor acts on the generator field to keep the motor armature current fixed at the value set by the operator. A speed limit control on the coiler provides automatic limitation to a strip speed only slightly above the strip speed on stand 5 and protects the coiler against any substantial rise in speed in the event of strip breakage.

Control Arrangements

There is a separate generator for each mill motor armature with all the machines for any one stand connected in series to ensure current sharing. In Fig. 4, we show the main circuit connections for stand 5, which is typical of all stands, the only distinction between stands being the number of armatures involved. The stand motor voltages are controlled to be equal at all times when the mill is running except that, as already mentioned, any stand may be working on reduced voltage to widen the "speed cone." The voltage control circuit for stand 1 is outlined in Fig. 5, the circuit for all stands being similar. Magnetic amplifiers and control exciters control the main generator excitation to give the fine degree of control and speed-dependent regulation required for a mill of this kind rolling such thin gauges.

The main mill speed control is carried out from four push-buttons, "thread," "run," "hold" and "stop," which are repeated on the various cabinets on the mill. The control operates through the motorised mill master control rheostat on to the field of the reference exciter. A selector switch gives choice of thread speed, while four other push-buttons on some of the cabinets allow "lower" and "raise" speed when it is required to reach intermediate speeds without the use of the "hold" push-button, "weld" speed when speed reduction is required to allow a coil weld to pass through the mill, and "slow stop" when desired to stop at a slower rate than is given with the normal "stop" push-button.

The main stand motor fields are supplied from a separate exciter, the field of which is controlled

by a motor-operated rheostat. Careful consideration has been given to the grading of these rheostats in order that the effect on rolling may be always uniform for small rheostat adjustments, being the same whether the motor is on full field or weak field.

The coiler motor voltage is controlled to be equal to the voltage of the pilot exciter driven by stand-5 motor. These two voltages are compared by a magnetic amplifier, which then supplies one of two fields of the coiler motor,

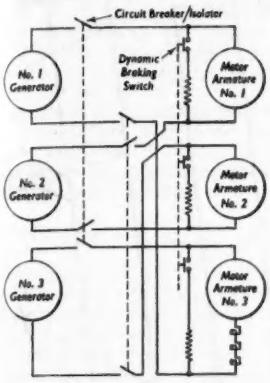


Fig. 4—Main circuit connections for stand 5

the second field being supplied from a constant voltage exciter controlled by a motorised rheostat. The control is such that the coiler motor field is strengthened as the coil builds up and that it takes into account such quantities as inertia compensation for changes in mill speed.

The automatic excitation control equipment for the main m.g. set synchronous motors is of interest, although it is not directly connected with the mill control. A network of metal rectifiers and resistances is supplied from potential and current transformers in such a way that the output is proportional to the reactive kVA in the synchronous motor supply. The output is applied to a magnetic amplifier which feeds the synchronous motor field. This system can be set up so that unity power factor is maintained by the synchronous motors or they can be made to run with a fixed reactive kVA input. Provision is made so that the motors can be run

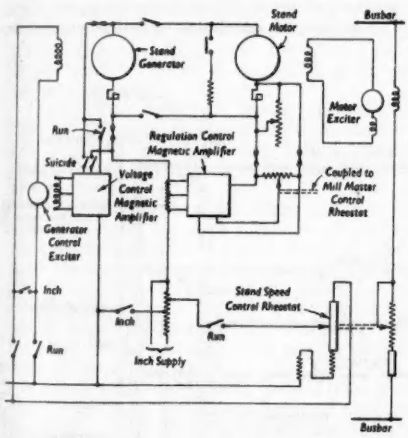


Fig. 5—Elements of voltage control system for stand 1

if required without automatic control and without the magnetic amplifiers, by taking a supply direct from the constant voltage exciter for the synchronous motor exciters.

The main electrical drives and control equipment described here were supplied by the English Electric Company, Ltd., the engineering work being carried out in collaboration with the engineering department of Richard Thomas and Baldwins, Ltd., and the electrical consulting engineers, McLellan and Partners.

Underground Gasification Trials in Great Britain*

No. II—(*Concluded from page 333, April 13th*)

A report has been published by the Ministry of Fuel and Power dealing with the trials in underground gasification carried out in this country between 1949 and 1955. This process, as is now generally known, involves the passing of air through a burning coal seam to produce a hot combustible gas which is brought to the surface for use. The report first deals generally with the background of underground gasification and gives some notes on work carried out in other countries. This article contains an abridgement of the main part of the report dealing with trials carried out at Newman Spinney, Barlborough, near Chesterfield, and near Bayton in Worcestershire, after preliminary work had been carried out by the Fuel Research Station on large blocks of coal in the laboratory. These proved to be of limited value, as the scale was too small and conditions were too remote from those obtaining in an underground coal seam under overburden pressure. Trials overseas had tended to go to the other extreme of speculating on a technique which might work and preparing something approaching a full-scale system for trial. The British trials were an attempt to compromise between these extremes and aimed to conduc each successive test on the minimum practicable scale (within the range of about 1–15 tons of coal gasified daily) to gain the required information for the next step in developing a sound technique.

Directional Drilling and Gasification (1953–55)

Recognition of the fact that the successful development of high-pressure linkage was likely to be a prolonged business made it desirable to seek alternative methods of creating linkage channels in the coal. It was learnt that Messrs. Boyles Bros. Drilling Company had developed an improved drilling technique in connection with long wall blasting. The method appeared able to drill accurately and for long distances into the coal seam at low cost. Trial No. 1 had shown in 1950 that over 150 tons of coal could be usefully gasified using a borehole in the coal only 50ft long. With longer boreholes and a correspondingly greater gas yield the cost of gas production should be very low. In order to reach an underground seam it is necessary either to drill from the surface or to sink a small shaft or drive an inclined gallery from the surface. Although techniques have been used to bend the direction of a borehole from the vertical to the horizontal, they are extremely expensive and it seemed preferable to plan the technique on the basis of taking the drilling rig underground by means of a small shaft or drift, which might subsequently be used for the air and gas supply lines. The construction of shafts and galleries is a well-understood technique raising no novel problems, and each skilled underground worker so employed should lead to the exploitation of some fifty times as much coal as he could extract by conventional mining. The cost of this preparatory work could be spread over so many boreholes in the coal and hence over so large a gas production as not to inflate unduly the cost of the gas. After considerable discussion it was decided that the original terms of reference, which were insistent that all operations should be conducted from the surface, could be relaxed so far as the preparatory work was concerned.

The contractors started drilling operations in 1953 into the face of the Fox Earth seam, which was excavated for the purpose at Newman Spinney, with almost immediate success in keeping the drill bit in the coal over long distances. Fifteen 4in diameter boreholes (some reamered out to 8in diameter) were drilled to a total length of over 850 yards, the last one to nearly 200 yards without passing out of the coal. The contractors were then asked to undertake directional drilling into the Rockmoor Minor seam from an excavation at Bayton. This was a much more difficult task, as the exposed coal was only 16in thick and the roof and floor were so nearly identical as to make it extremely difficult to recognise from the chippings when the drill passed out of the coal whether it had gone up into the roof or down into the floor. Nevertheless, after abandoning two preliminary holes four more holes were drilled which for most of their length were in coal, the longest being 290ft. These successes under difficult conditions justified the construction of a miniature system of shafts and underground galleries to enable the drilling rig to be used underground under conditions similar to those envisaged for a full-scale system. Four parallel 200ft boreholes were successfully drilled underground from gallery to gallery in the coal for trial No. 45.

* "British Trials on Underground Gasification, 1949–1955." H.M. Stationery Office. Price 8s.

Systems Based on Directional Drilling

The preliminary gasification trials based on directional drilling were planned to explore the possibilities of two different methods for gasifying the boreholes in the coal. In both methods all men would be brought to the surface before ignition of the coal.

(*a*) *Open Boreholes.*—Connection for air and gas made to each end of the borehole in the coal by driving parallel galleries, and drilling between pairs of galleries a number of parallel boreholes at appropriate spacing. It would from experience seem certain that at normal air rates the reactions would move along the boreholes in the direction of air flow, thus necessitating occasional reversal.

(*b*) *Blind Boreholes.*—A more convenient arrangement would be to drill into the coal without attempt to make intersection with another gallery at the far end. In its simplest form two parallel boreholes could be drilled at no great distance apart, connection being made at the far end by burning through or by electrolinkage. Air passed up one borehole should result in gas coming out of the other.

An alternative would be to use each borehole as an independent unit, the air being carried up to the far end of the hole by a pipeline smaller than the borehole and thus allow the gas to pass back between the pipe and the borehole wall. This would have the effect of heating the pipeline and so of preheating the air supply. As a result the reaction should not move back to the face other than very slowly as the coal is exhausted and the end of the pipeline burnt away. Reversals would then not be necessary.

Gasification Trials

The trials at Newman Spinney were all designed to throw light on the possibility of using blind boreholes and in particular to confirm whether preheated air would in fact slow down sufficiently

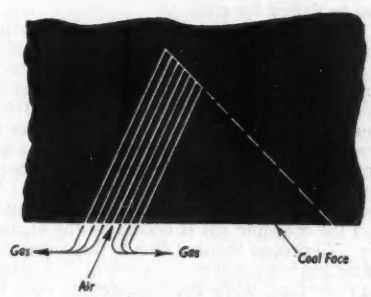


Fig. 4—Plan for trial No. 30

the movement of the reaction back to the face to avoid reversals.

The trials at Bayton were all on open boreholes. Those conducted from the exposed face were planned on the same lines at trial No. 1, each with two vertical boreholes drilled to intersect the borehole in the coal, one at the far end and one about 45ft in from the face. Preheated air was tried out in these trials also.

Multiple Exit Boreholes

Trial No. 30 (Fig. 4) at Newman Spinney was based on a drilled system consisting of seven parallel boreholes (4in diameter) at 3ft spacing drilled some 60ft average distance in from the face. Another hole about 85ft long was drilled in obliquely to intersect and so to connect these seven holes near to their far ends. The centre hole of the seven, to be used as the air supply, was lined with aluminium tube to avoid cross

percolation. Arrangements were made to preheat the air supply, using paraffin, and ignition occurred while the air temperature was not much in excess of 100 deg. Cent. The arrangement of one inlet borehole with six outlet boreholes was to maintain a high forward linear velocity in the air passing into the reaction and a low exit velocity in the gas passing back from the reaction. It was hoped this might help to prevent the reaction moving towards the face. Without preheating the reaction appeared controllable and stationary at the far end up to an air inlet rate of about 5000 cubic feet per hour (say, 6ft per second hot linear velocity down the exit boreholes). With preheating to 300–400 deg. Cent. the calorific value of the gas was improved, exit gas temperatures fell and the reaction appeared to remain stationary at the far end of the borehole at air inlet rates approaching 20,000 cubic feet per hour (S.T.P.). These conclusions were provisional only as the trial was a complex one to conduct, the scale was too small for final results and the hot gas from the exit tended to fire the coal face despite arrangements for water cooling.

Trials with Blind Boreholes

Trials with blind boreholes are in progress at Newman Spinney. A heading has been driven into the exposed face of the shelf to enable boreholes to be drilled near the horizontal into the Fox Earth seam on both sides. A shaft is also being sunk to the levels of the three seams on this site, from which further blind boreholes can be drilled for trial.

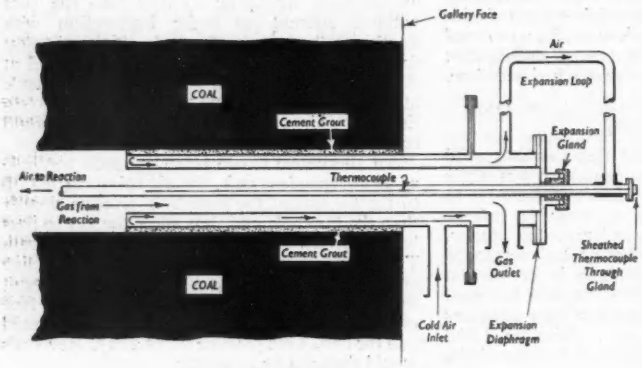


Fig. 5—Trial No. 49 with blind borehole

Trial No. 49 is in operation in a nearly horizontal borehole about 160ft long and of 8in diameter drilled from the heading. The air supply is provided by a 1in diameter steel pipe to deliver 10,000 cubic feet per hour at 60 lb per square inch pressure loss. Not only does this give a maximum cooling effect to the pipe walls but also will show, by reduction in pressure loss, any burning back of the air supply pipe. The incoming air is preheated by the outgoing gas and the outgoing gas is cooled by the incoming air. To protect the coal face in the gallery from becoming hot a heat exchanger (Fig. 5) is grouted into the face, while the heading has been kept ventilated by an air circulation of about 60,000 cubic feet per hour.

During the first month of operation the following preliminary results have been obtained :—

(*a*) About 40 tons of coal have been gasified at an air rate of about 11,000 cubic feet per hour.

(*b*) The calorific value of the gas is still over 85 B.Th.U. per cubic foot and has averaged about 100.

(*c*) The pressure loss indicates that no burning back of the inlet pipe has yet occurred, nor does the reaction yet appear to have begun to pass back towards the face.

(*d*) The forward thermocouple, 135ft in from the face, which initially exceeded 1000 deg. Cent., dropped in a few days to about 350 deg. Cent. and is now down to about 250 deg. Cent. (intermediate thermocouples showing corresponding drop) and the exit gas temperature before entering the heat exchanger has dropped from 500 deg. Cent. to under 450 deg. Cent. This fall-off in temperature is attributed to the greater loss of heat at the far end through roof and floor as the burnt out area has increased in size.

(*e*) The decrease in temperature of the air preheat has been accompanied by a corresponding decrease in pressure loss.

(*f*) The temperature of preheat of the air is sensitive to the air rate. Dropping the air rate from 11,000 cubic feet per hour to about half increased the air preheat temperature by about 50 deg. Cent. in a few minutes. Similarly an increase in air rate dropped the preheat temperature.

(*g*) The gas is leaving the heat exchanger at about 350 deg. Cent.

This trial is not yet complete and other trials are required, especially with larger air supply tubes of greater length. If this blind borehole technique can be developed successfully it should result in systems easier to operate (no reversals) and cheaper in preparatory cost.

Open Boreholes

Three trials were carried out with reversals at Bayton in the Rockmoor Minor seam. In the first one the length of 4in borehole in the coal which was gasified was about 200ft long, and in others about 100ft long. All took the same form of a borehole near the horizontal in the coal with two vertical boreholes drilled down to intersect. The system, after ignition, was operated from these two vertical boreholes, one as upcast and the other as downcast, with reversals if necessary. In view of the thinness and unsatisfactory character of the seam it was not to be expected that large tonnages of coal would be gasified. Nevertheless gas of satisfactory quality was produced and additional information was gained on borehole gasification and the use of preheated air supply. One more span has been prepared but its gasification has been postponed in favour of the preparations for major trial No. 45. The span used for one trial was excavated from the face as far as the first vertical borehole. This showed that the reaction in general had spread only a very short distance towards the face from this borehole although the coal and shale roof and floor several feet from the burnt out seam were hot and steaming for weeks after exposure.

Trial No. 45. Shafts and Galleries

The object of this trial was to prove the practicability of directional drilling underground and to operate a multiple borehole system to gasify if possible some 2000 tons of coal during an uninterrupted run of about four months. With an air rate of 100,000 cubic feet per hour about

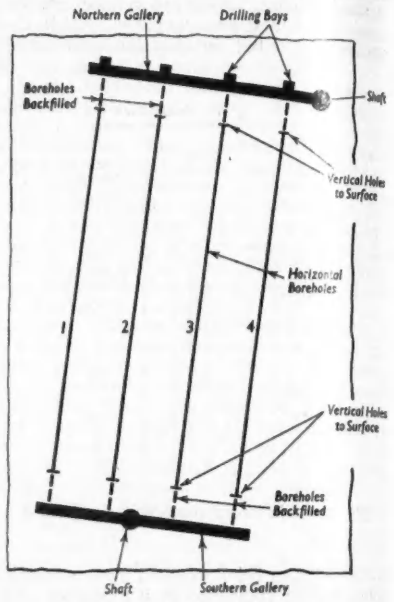


Fig. 7—Directional drilling underground, trial No. 45

15 tons of coal should be gasified daily yielding about 100 therms per hour (capable of generating nearly 750kW).

The system was based on the " open borehole " method as being further advanced than the " blind borehole " method, and not as necessarily the better method in the long run. Four parallel boreholes 30ft apart were drilled in the Broseley seam at Bayton from one gallery at coal level to another 200ft away. The galleries ran down dip so that the boreholes were nearly horizontal (average depth about 80ft). The two shafts giving access to the galleries were 6ft 6in in diameter (see Figs. 6 and 7). For the trial it was desirable to exercise independent control of the four borehole reactions and vertical boreholes were drilled, two for each horizontal borehole, to intersect at about 15ft in from the gallery faces. The horizontal boreholes were then sealed be-

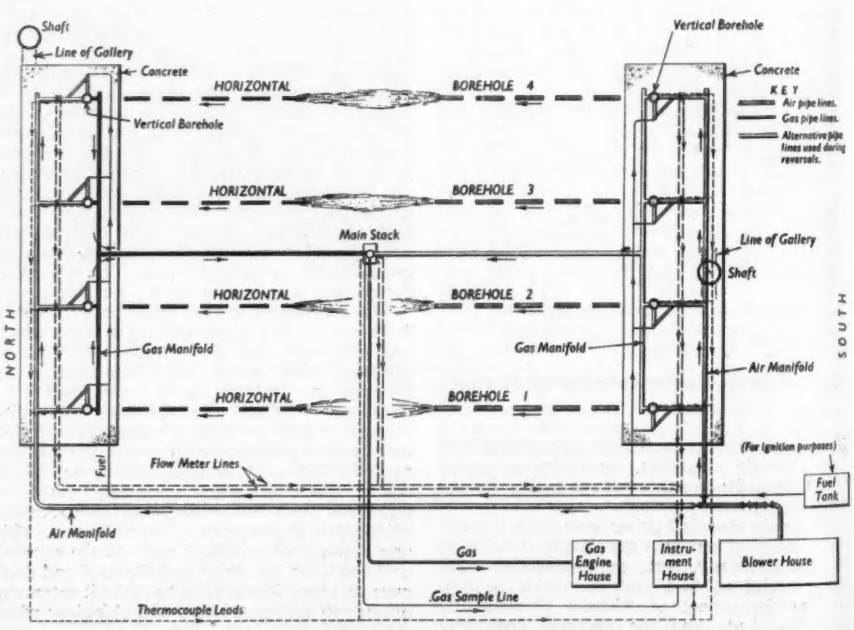


Fig. 6—Diagrammatic layout of trial No. 45

tween these intersections and the faces. Means were provided for preheating the air supply at the surface by means of oil. The shafts were partially filled to seal the galleries and vertical boreholes to the galleries were used for sampling purposes.

The preparatory costs for this trial totalled £9607. If 60 per cent of the energy in the 2000 tons of coal is brought to the surface in usable form the total yield is 300,000 therms, and the cost of the preparatory work would be 7·7d. per therm. This would be prohibitive. But in a complete system boreholes would be drilled on both sides of each gallery so that each set of boreholes would carry the cost of only one shaft and gallery. The preparatory cost to be allocated to the four boreholes would then be £5338 or 4·3d. per therm.

This system is of course far below the commercial scale where each shaft and gallery might serve upwards of fifty reactions in boreholes 200 yards long. The preparatory costs per therm would thus be much reduced.

Trial No. 45. Gasification

The four spans were ignited in succession over a three-week period using air preheated to about 800 deg. Cent. at the oil preheater on the surface. On spans 2 and 4 there was a considerable pressure rise during ignition which only slowly dropped to a normal operating pressure. This pressure rise may be associated with the wooden liners in the horizontal bore becoming choked with debris.

Over the thirteen weeks since first ignition about 1200 tons of coal were gasified and the calorific value of the gas showed an average of 70 B.Th.U. per cubic foot over the period.

Leaks between spans 2 and 4 and the gallery began to develop quite early (due to pressure rise as noted above) and by now there may be some lateral connection between some of the pairs of boreholes themselves. During the twelfth week a leak developed to the surface on No. 4 span due to an old 13½in diameter borehole which was insufficiently "sealed off" so providing a line of weakness to the surface; analysis of the leakage gas was similar to No. 4 span gas.

Features which have appeared during the trial have been:

(*a*) Temporary drop in gas quality following reversals.

(*b*) Generally speaking a better calorific value associated with a high air rate. (Spans have been operated at over 50,000 cubic feet per hour each.)

(*c*) Preheat of the air, other than for ignition purposes, seems to have failed to have recognisable effect on gas quality or temperature, although preheat tests were carried out for a very limited period only. Further tests may be done with preheat.

(*d*) Reversals have been dictated from time to time by the upcast gas temperature becoming excessive (e.g. above 600 deg. Cent.) and endangering the seal between the casing and the ground.

(*e*) For some days a procedure was operated involving sixteen hours shut down at night with eight hours operation by day. The result was a grave deterioration in gas quality, but possibly due to working at atmospheric pressure thus allowing inseepage of water. It is proposed to repeat under pressure and for shorter periods, the object being to simulate the serving of peak demand for power.

(*f*) During the twelfth week vertical holes were drilled over span 2 (coal depth 80ft) and temperatures taken every 5ft from the surface with the following result: 5ft, 65 deg. Fah.; 10ft, 95 deg. Fah.; 15ft, 138 deg. Fah.; and 17½ft, 212 deg. Fah. (at this level the heavy steam formation appeared to constitute some danger and drilling was discontinued). This heating of the overburden presumably parallelled by equal heating downwards through the floor seems to match the heat not accounted for, directly and indirectly, in the gas.

(*g*) Subsidence of the surface started a few weeks after ignition and has proceeded as might be expected over the gasified area to a depth of about 1ft 6in. Forty-one survey points have been and are being kept under observation.

(*h*) The trial will be continued with variations for another several months so long as useful information is being obtained.

For a considerable period during this trial the small-scale generating plant has been in operation on full load. The period of running has enabled observations to be made on gas scrubbing, &c. Some tests have also been carried out to obtain data on the tar and dust contents of the outflow gases.

Performance Summary: Directional Drilling

(*a*) Many boreholes have been drilled near to the horizontal, most or all of their length being in the coal, up to nearly 200 yards long (*cf.*—50ft by high pressure and 100ft by electro-linkage).

(*b*) Such boreholes have repeatedly been gasified, yielding usable gas even in grossly unsatisfactory seams.

(*c*) The tonnage of coal usefully gasified depends upon the kind and thickness of coal and seam but has sometimes exceeded 10 tons per yard of length.

(*d*) Trials have been carried out on two methods of applying directional drilling in preparing a system and further work is necessary to determine which is the better.

(*e*) Shafts have been sunk, galleries driven, and four boreholes drilled to gasify a panel of coal containing about 2000 tons. During the first three months about 1200 tons of coal have been gasified, the average calorific value of the gas being 70 B.Th.U. per cubic foot. The trial continues.

Review and Conclusions

(*a*) The trials have shown that gas can be produced by a variety of methods of underground gasification and that this gas can be used to generate electricity.

(*b*) Most of the earlier trials were conducted in single spans, i.e. single reactions. Latterly multiple spans have been successfully used, thus beginning to approach, in principle, the full-scale applications of the process which must consist of many reactions in simultaneous operation.

(*c*) Nearly 5000 tons of coal have been gasified in some fifty trials and rates of over 20 tons daily have been maintained (sufficient to generate up to 800kW) on single systems.

(*d*) Coal seams which cannot be mined economically can and have been gasified, with a minimum of manpower underground for the preparatory work. There are said to be hundreds of millions of tons of such unmineable coal in this country.

(*e*) The most promising method for quick development is based on directional drilling, on which work did not start until late in 1953. The earlier techniques of high-pressure linkage and electro-linkage have temporarily been discarded as likely to involve excessive time and effort for full-scale application.

(*f*) Throughout the trials regard has been paid to the likely costs of gas and electricity in full-scale production, so that the trials could be terminated if the final result seemed likely to be impracticable or uneconomic. But with increasing experience and changes in technique the likely cost has fallen, while at the same time the cost of power station coal has risen, both factors operating in favour of the process.

(*g*) The trials, though large by laboratory standards, have been on a small scale compared with a commercial system gasifying over a thousand tons of coal daily and such costs as have been calculated are, therefore, open to question. One or more pilot scale installations, each gasifying upwards of 50 tons of coal daily and generating electricity, must be operated if firm costs are to be obtained.

Uganda Electricity Board.—The Uganda Electricity Board has published its eighth annual report and accounts for the year ended December 31, 1955. The report states that "the water power resources of Uganda are now making a significant contribution to the economy of the country." Nearly 80,000,000 units, or 99·53 per cent of the electricity sold by the Board, were generated at the Owen Falls hydro-electric scheme. The Board has been pressing forward with extensions to the existing distribution network and with the planning of the further extension of electricity supplies.

Report on Proposed Firth of Forth Road Crossing

An interim report of the technical panel set up by the Minister of Transport and Civil Aviation to consider the relative merits of the Forth subway and bridge proposals has been published as a White Paper. The technical panel was appointed in May, 1955, and consisted of Sir William Halcrow, Mr. Gilbert Roberts (of Messrs. Freeman, Fox and Partners), and Mr. Shirley Smith (of the Cleveland Bridge and Engineering Company, Ltd.).

The subway scheme was proposed by Mr. G. A. Maunsell, and involved construction of a massive reinforced concrete subway 3800ft long, supported on piles. The subway would lie on or above the bed of the estuary and would be joined by ramps and embankments at each end to the approach roads on shore. The proposed bridge was designed by Messrs. Mott, Hay and Anderson, and consists of a suspension bridge with a main span of 3300ft and suspended side spans of 1260ft each. At each end of the bridge massive anchorages would be provided and also reinforced concrete approach viaducts to link up with the new approach roads.

The panel considered that the subway, together with its ramps, would constitute a restriction in the effective waterway of the estuary amounting to 25 per cent. Before the scheme could be accepted it would be essential to carry out tests on a hydraulic model to determine what effect this restriction would have on the regime of the river and the possible effects of scour and drag. In view of its unique construction, involving a 700ft long segment spanning the deep channel near the Fife shore, the subway scheme could not be considered as immune from risk of disaster occasioned by shipwreck, it was stated, as were all other underwater subways so far built, which lay in dredged trenches and were covered over.

The estimated cost of the subway scheme, including approach roads, was £9,666,000 (exclusive of the cost of a special temporary dry dock), and of a bridge providing the same facilities, £9,960,000. The panel's estimate of the cost of a subway exceeds Mr. Maunsell's by £2,855,000, due, it is stated, to the subway not having been designed to conform to standards of roadway width, clearance, gradient, ventilation, &c., which were acceptable to-day. Other matters that increased the cost, in the panel's opinion, were the necessity of ensuring water-tightness of the concrete and the substitution of bored piles for "Gambia" piles, which were not considered suitable. There would also be an increase in on-cost charges due to the longer construction period necessitated by the increased quantity of work. The cost of operation of the subway would be much higher than the maintenance of the bridge, and if the capitalised cost of each were included in the estimates, the bridge would be the less costly scheme. Assuming that all went smoothly, the time of construction of the subway would be from six to nine months less than that of the bridge, but the kind of work involved in the construction of the subway was more susceptible to hazard, the panel's report continued, and in the event of any trouble arising the construction time would, of course, be extended by the period of delay.

In all the circumstances, it was concluded, the bridge scheme appeared to offer a more satisfactory solution than the subway to the particular problems presented by the site.

Barium Titanate Accelerometers and Strain Gauges

MINIATURE accelerometers and strain gauges using barium titanate transducers suitable for vibration testing have been developed by The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. These two new devices are the type-E barium titanate accelerometer (Fig. 1) and the barium titanate vibration strain gauge (Fig. 2).

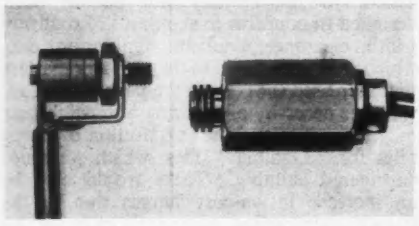
Principle of Operation

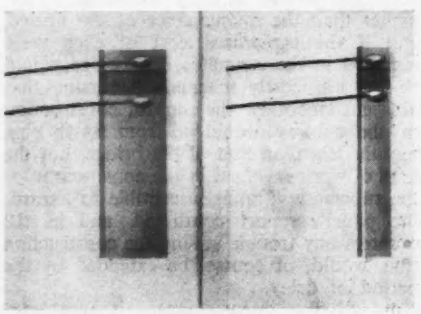
Barium titanates are classed as ferro-electric materials, which means that they can, by the application of a large d.c. voltage, be permanently polarised electrically, rather as a ferromagnetic material such as iron can be polarised magnetically. When properly prepared and polarised barium titanate behaves as a piezoelectric crystal with a very high activity. When such a crystal is compressed, the strain in the crystal gives rise to a minute potential difference across the faces which is proportional to the degree of compression. Conversely, if a potential difference is applied to those faces, the crystal itself will suffer a very small decrease in size.

Under repeated alternating compression and expansion a piezoelectric crystal will generate an electrical charge proportional to the forces being applied to it. This is what happens in an accelerometer, where the crystal is fixed between a rapidly vibrating surface and an inertia weight. The electrical charge is fed to a detector with a suitably high impedance, such as a cathode follower, and the signal can then be observed on a cathode-ray oscilloscope. This method gives the frequency and amplitude of the vibrations. The barium titanate strain gauge is a simpler device, consisting only of a barium titanate crystal with two leads attached. With it resonant frequencies can be determined in vibrating mechanical structures, as well as the approximate relative strengths of such vibrations. The great sensitivity of the barium titanate transducer depends on the dielectric constant and piezoelectric activity being very high—considerably higher than those of quartz.

Construction and Operation

The G.E.C. type-E Barium Titanate Accelerometer is designed to detect and measure shocks and vibrations on any object over a wide range of operating conditions (Fig. 1). It consists of a circular disc of barium titanate about $\frac{1}{4}$in thick and $\frac{3}{8}$in in diameter, which is silvered on both sides and sandwiched between two pieces of brass. One piece forms the base and is terminated by a 2 B.A. stud for fixing purposes. The other acts as an inertia weight which converts the vibrations in the equipment to strains in the ceramic. These strains then generate a piezoelectric charge, proportional to the acceleration applied to the base, which is collected by a coaxial screened cable. The signal is taken to a detector with a suitably high impedance, such as a cathode follower, and can be observed on a cathode-ray oscillograph. The accelerometer is only $\frac{3}{4}$in long and can easily be attached by its stud to any piece of equipment whose vibration characteristics are to be studied. The loading effect on the apparatus under test is limited by the overall weight, which is only 11 grammes (18 grammes with screening can).





Figs. 1 and 2—(Top) Barium titanate accelerometers with and without screening. (Bottom) Vibration strain gauges of barium titanate, which can be used either for detecting or for exciting vibrations

The response of the accelerometer to accelerations of up to 1000 *g* is linear and its charge sensitivity of about 5pC/*g* gives a voltage output of about 20mV/*g*, using conventional circuitry. The accelerometer will detect and record frequencies in the range 20 c/s to 20 kc/s and between 40 c/s and 10 kc/s it is accurate to within ±10 per cent. A point of interest is the construction of the base, which is reduced in thickness just above the mounting stud. This reduction effectively reduces spurious signals caused by strains in the object under test, and it also reduces the effect of transverse accelerations. The transverse sensitivity of the device is less than 5 per cent of the axial sensitivity, so that the direction of vibration can readily be determined by the position in which the unit is mounted.

Operation of the accelerometer is effective at any temperature between −50 deg. Cent. and +100 deg. Cent.; if this temperature is exceeded the piezoelectric properties can be restored by repolarisation. The voltage sensitivity varies with temperature to the extent of only 0·15 per cent per degree Centigrade. Each unit is individually calibrated at a particular temperature and is supplied with a 32in length of screened cable.

For certain applications it may be preferable to use a screened accelerometer. A screened version of the type-E unit has, therefore, been designed, with a performance very similar to that of the unscreened unit. The aluminium screening can makes the device somewhat larger, measuring $\frac{3}{4}$in by $1\frac{1}{4}$in. (Fig. 1) The method of fixing to the test object is equally simple and the screen can be removed if desired.

A typical application is illustrated in Fig. 3, which shows a G.E.C. barium titanate accelerometer arranged to form part of the resonant search equipment for testing the microphony of special quality "Osram" valves. Here the accelerometer serves as a monitor for the vibration wave form and is also used as part of the control circuit giving constant acceleration. This test rig is installed at the Hammersmith works of the M.O. Valve Company, Ltd.

The barium titanate vibration strain gauge was developed for measurements of blade vibrations on rotating turbine wheels but it has applications to similar problems. It is two or three thousand times as sensitive to alternating strain as a typical wire resistance strain gauge, but does not respond to steady strain.

The gauge consists of a thin bar of polarised barium titanate with silver electrodes on the two major faces. The electrode on the lower face is extended round one edge on to a small part of the upper face and the leads are soldered on to the two electrodes on the upper face. The under side of the gauge is attached to the object to be tested by a suitable cement. When the object vibrates, the alternating strains in the plane of the gauge produce an alternating charge on the electrodes, which is fed to a suitably high impedance detector. Unlike the accelerometers, the strain gauges are not supplied calibrated, because they are intended primarily for the determination of the various frequencies at which resonant vibrations occur in mechanical structures, and of the approximate relative strengths of such vibrations. They will operate in the frequency range 20 c/s to 50 kc/s.

An advantage of the barium titanate strain gauges is that they can be used either to detect vibrations or to excite them by the reverse process of applying an alternating voltage to the crystal. This considerably increases the scope of vibration measurements which can be made on mechanical structures.

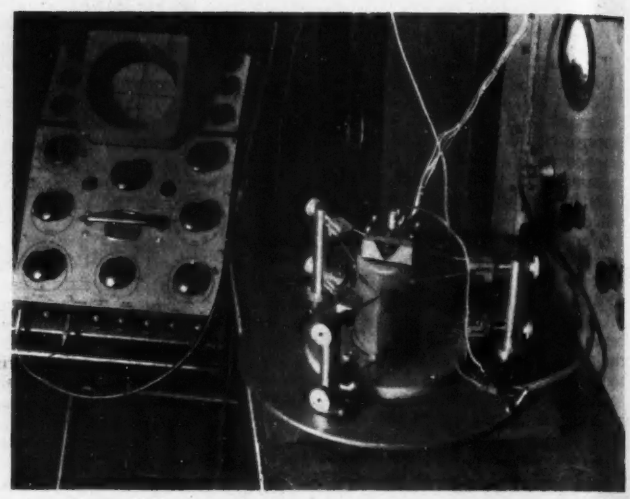


Fig. 3—Barium titanate accelerometer forming part of resonant search equipment for microphony testing of special quality "Osram" valves

The strain gauges are made in two standard sizes, measuring $\frac{1}{4}$in by $\frac{1}{4}$in by 0·035in, and $\frac{1}{4}$in by $\frac{1}{4}$in by 0·035in, either of which can be used for detection or excitation. The sensitivity is of

Fig. 4—Barium titanate vibration strain gauges being used for testing turbine blade vibration

the order of 0·1V output for an alternating displacement of 1 part in 10^8. Like the accelerometer, the strain gauge will operate at temperatures between −50 deg. Cent. and +100 deg. Cent.; if this temperature is exceeded the piezoelectric properties can be restored by repolarisation.

In Fig. 4 we show one of the new barium titanate vibration strain gauges being used for vibration testing on a turbine blade at the Fraser and Chalmers Engineering Works of The General Electric Company, Ltd.

"Auris" Gas Turbine

THE gas turbine which was built by the British Thomson-Houston Company, Ltd., and was installed in November, 1951, in the 12,000-ton deadweight oil tanker "Auris," of the Shell Tanker fleet, has operated at full power for 17,510 hours. When fitted in the ship the unit, a description of which appeared in THE ENGINEER of February 23, 1951, replaced one of the four Hawthorn-Sulzer four-stroke, eight-cylinder diesel engines, each of which developed 1105 b.h.p. and was direct coupled to a B.T.H. double-unit 830kW alternator supplying power to a B.T.H. single unit a.c. propulsion motor of 3750 s.h.p.

During the intervening years the gas turbine, which operates on the open-cycle system and has a rated output of 1200 b.h.p., has been subjected to an extensive series of tests, under service conditions, to establish data concerning performance of the turbine itself, and of materials, and also to study the problems incidental to the burning of boiler oil. Corrosion and fouling of the turbine blades were the two major problems set by the operation of the gas turbine on boiler oil and during the first three years in service it was necessary to use diesel fuel for part of the time. However, the use of better materials and other improvements have overcome initial difficulties so that it has been possible to burn boiler fuel only for some considerable time past.

Rotor with high-pressure blades in the foreground

A year ago the high-pressure part of the turbine was opened up and cleaned and since then some 500 tons of boiler oil, varying in viscosity from 1200 to 1500 seconds Red 1 at 100 deg. Fah., have been consumed. Recently, the high-pressure part of the turbine has again been opened for inspection and was found to be clean as when previously examined. The photograph reproduced herewith illustrates the condition of the blading. The employment of special materials has enabled the corrosion of those parts which operate at a red heat to be prevented while the problem of the accumulation of deposits on blades has been solved by the development of a technique which removes the combustion deposits as they are formed. Several years' service at sea have amply demonstrated the mechanical reliability of this gas turbine, and it is considered that the encouraging results from using boiler oil remove the remaining doubts regarding this form of prime mover.

The other parts of the unit, consisting of the air compressor, heat exchanger and low-pressure turbine, have not required to be opened up for cleaning. Salt spray drawn into the compressor with the air supply is removed by water injection while steam jets are provided as a means of preventing any accumulation of soot in the heat exchanger tubes.

Based on the results from the small experimental unit the Shell Petroleum Company, Ltd., feels reasonably certain that the new large gas turbine of 5500 h.p., which is being built by the British Thomson-Houston Company, Ltd., and which will be installed in the "Auris" in the near future, will have a fuel economy comparable with a steam turbine, and be able to operate on the same low-priced fuel. Maintenance costs will be very much lower. Further development work remains to be carried out, particularly with respect to manœuvring problems, and this will proceed when the "Auris" goes to sea with the new turbine fitted, which drives the propeller through gearing.

Modernisation Plans for British Railways

THE British Transport Commission has announced the programme of improvements and re-equipment to be carried out in 1956 under the £1200 million modernisation plan for British Railways. A forecast of some of the principal schemes likely to be started in 1957 has also been given. It is pointed out that the reduction of £12,000,000 recently announced in the 1956 capital investment programme for British Railways means some slowing down of minor works and of the delivery of some equipment, but will not affect the major developments planned.

Five-year programmes are in preparation for additional bridge renewals to keep in advance of future requirements. Meanwhile, the annual renewal programmes will continue to cover ordinary maintenance requirements and will, in addition, provide for the strengthening of the track in various places to prepare for higher speeds.

In connection with track widening plans, contracts have already been placed in connection with the construction of three new tunnels between New Barnet and Potters Bar, at an estimated cost of some £2,750,000. This work will enable two additional tracks to be laid between these points, and remove a long-standing bottleneck on the East Coast route to Scotland. The work is also a prerequisite to electrification of this line, which is included in the main plan. A start will be made with the provision of two additional running lines on certain other short sections of the main line from King's Cross, to eliminate present bottlenecks.

An important improvement which will start this year is a new track layout, coupled with the installation of modern colour-light signalling, at Manchester (Victoria). Additional schemes for the introduction of colour-light signalling and the concentration of signal-boxes, costing over £600,000, will be completed in the next two years.

In the Eastern Region, the construction of two branch lines to serve new collieries at Bevercotes and Cotgrave, Notts, will be started; and in Scotland lines will be built to serve new collieries at Glenochil in Clackmannan and at Killoch in Ayrshire. In the North Eastern Region work will start on new rail welding and track pre-assembly plant at Dinsdale and a new signal engineering works at York.

Electrification Progress

The extension of electrification from Shenfield to Chelmsford will be completed in June this year and to Southend (Victoria) early in 1957. This will form the basis of further electrification along the Eastern Region main lines to Ipswich, Clacton, &c. Details are given on page 359. The full cost of the extensions to Chelmsford and Southend is estimated at £2,500,000.

Planning in connection with the associated scheme for the electrification of the line from Fenchurch Street to Tilbury and Southend is well advanced. The extensive preliminary engineering works involved in this scheme include the reconstruction of Barking Station, the re-arrangement of the running lines and flyover junctions, and new freight facilities. Work in the Barking area will start this year.

A start will also be made on the scheme for the electrification of the Eastern Region suburban lines from Liverpool Street to Enfield and Chingford, Hertford, and Bishops Stortford, estimated to cost £6,500,000. The electrification of the line between Manchester and Crewe will also be put in hand this year. As already announced, this is a "pilot" scheme for electrification between London, Birmingham, Liverpool and Manchester, utilising the standard 25kV alternating current system which is to be adopted subject to the approval of the Minister of Transport and Civil Aviation. Preliminary work will also begin on the extension of the Southern Region electrification from Gillingham, Maidstone East and Sevenoaks to Sheerness, Margate, Ramsgate, Folkestone and Dover and from Ashford to Ore (Hastings).

Diesel Traction

As already announced, orders have been placed for 174 main line diesel locomotives, at a cost of over £11,000,000, and delivery of these locomotives will start in 1957. During 1956-57 over 400 more diesel shunting locomotives will be brought into use to replace steam locomotives.

Expenditure on diesel mutiple-unit trains during the next two years will be about £23,000,000, covering the construction of some 1750 vehicles. Diesel maintenance facilities are to be provided at a cost of £1,500,000 at Norwich, Lincoln, Leith, Birmingham, Hastings, Cambridge, Stratford, Darlington, Bristol, Cardiff, Westbury and other places.

In 1956 and 1957 a total of some £26,000,000 will be spent on the construction of new passenger coaches, including multiple-unit electric vehicles with improved bogies, and corridor main line vehicles. All passenger-carrying vehicles will be of steel construction apart from a limited number of multiple-unit coaches, which will be built in light alloy. The modernisation plan envisages the replacement of all timber-bodied passenger coaches within the next seven years, and about 2600 passenger train vehicles of all types will be built this year. Of the 70,000 new freight wagons to be built this year, 47,500 will be supplied by contractors and the remainder built at British Railways works. About £500,000 will be spent on the provision of continuous brakes on goods vehicles in 1957 and about £3,000,000 will be spent in this connection in 1958.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

DETERMINATION OF KNOCK-RATING OF MOTOR FUEL

No. 2837–38 : 1956. Price 6s. This new volume establishes as national standards the Institute of Petroleum specifications IP 44/55 (A.S.T.M. D.357–53) for the motor method and IP 126/55 (A.S.T.M. D.908–53) for the research method of determining the knock characteristics of fuels for use in spark-ignition engines, the first method being relatively severe—900 r.p.m., spark 19 deg. to 20 deg. B.T.D.C. —and the second relatively mild—600 r.p.m., spark 13 deg. B.T.D.C. The specifications give details of the conduct of the tests and appendices give a description of the C.F.R. engine, guide tables of compression settings against octane number for standard knock intensity, the procedure for adjusting the micrometer to record cylinder setting, specifications for iso-octane and n-heptane, instructions for facing the Stellite valves and seats, and the use of precision data.

Industrial and Labour Notes

Overseas Trade

The provisional figures about the United Kingdom's overseas trade in March show that exports reached a record value of £269,600,000. In the first quarter of this year, the average monthly value of exports was 4 per cent higher than in the comparable period of last year, and 6½ per cent above the rate for the whole of 1955.

The value of imports in March was £330,300,000, which brought the monthly average for the first quarter of this year to £328,500,000. This was 2 per cent less than in the corresponding period of 1955, but 1 per cent more than for the whole of last year. Re-exports in March, at a value of £13,300,000, were a little lower than in the two preceding months. The excess of imports over total exports in March was thus £47,400,000, which was £2,100,000 less than in February. In the first quarter of this year, the visible trade deficit averaged £57,000,000 a month, which was £15,000,000 below the average for the whole of last year.

Federation of British Industries

The annual general meeting of the Federation of British Industries was held in London on Wednesday of last week. The thirty-ninth annual report surveys the many activities of the Federation, at home and overseas, during 1955, and records that at the end of the year the membership totalled 7445 firms and 286 trade associations.

At the meeting, Sir Graham Hayman was re-elected president for a second year. In his presidential address, Sir Graham commented on the Federation's achievements over the past year and also referred to several aspects of the economic and industrial situation. In this context, he spoke about this country's need for more exports and suggested that, at the present time, we were not making sufficient use of the chances presented by the expanding field of world trade. Certain areas were providing entirely new openings for exports, and our main competitors were very much alive to the opportunities thus presented. In some fields, Sir Graham acknowledged, our exports were holding and improving upon their position, but there could be no relaxation of effort. The contraction of home demand, which was now evident, served temporarily to aggravate the position, and the process of adjustment would take a little time, but, Sir Graham added, the target should not be in doubt. He thought the Government's improved export credit facilities would help, but careful market surveys and the personal visits of executives at the right level were the essentials. This, however, Sir Graham continued, did not automatically resolve the problems of price and delivery, but it was an essential prerequisite to successful market development. There might be no common formula of approach, but there should be a common determination to sell more of our goods overseas. He went on to stress that the progress of our whole economy depended greatly on the application of ever-improving techniques and inventions. The quality of our scientific effort was not in doubt, he said, but we needed also the human resources to operate the increasingly complicated equipment and organisation of modern industry.

The F.B.I., Sir Graham said also, had noted with satisfaction the Government's recent pronouncements on the plans for extending the availability of trained manpower. That, he observed, was a field in which industry had a vital part to play, and employers should take the broad view and accept the fact that it was in their own interests for the employees to have the widest degree of training compatible with their ability.

Proposed Inquiry into the Motor Industry

On Thursday of last week, the executive of the Confederation of Shipbuilding and Engineering Unions held a meeting at York. Afterwards it was stated that the Confederation proposed to ask the Government to make an immediate fact-finding inquiry into the British motor-car industry. It was thought that such an inquiry ought to include design, capital investment, profits, export organisation, restrictions, and distribution costs. Mr. H. G. Brotherton, the president, said that it was the first time the Confederation had asked the Government to institute an inquiry of this nature ; an approach was to be made forthwith to the President of the Board of Trade.

Railway Freight Charges

Last week, in the House of Commons, the Minister of Transport and Civil Aviation, made a further statement about railway freight charges. He said that he had received from the permanent members of the Transport Tribunal a memorandum containing an objective survey of the British Transport Commission's financial position since 1947, which showed the serious deficiencies of revenue in relation to expenditure. On this basis, the members of the Tribunal had recommended the making of regulations authorising the increases in railway charges proposed by the British Transport Commission.

The Government still considered, however, the Minister stated, that it was in the national interest to authorise for an interim period of six months lower increases than those recommended. The Minister explained, therefore, that he would lay before the House regulations authorising the Commission, as from April 23rd, to increase the railway freight, dock and canal charges now in operation, by 5 per cent generally, but by 7½ per cent in the case of railway freight charges for merchandise by goods train in consignments of under 1 ton and for merchandise by passenger train, and by 12½ per cent in the case of railway freight charges for returned empties. This, he added, was on the clear understanding that these charges would have to be re-examined in the light of the circumstances which would exist in six months' time.

Export of Tractors to China

Last week it was stated that the Board of Trade had granted export licences for the shipment of a limited number of agricultural tractors to China. In reply to questions in the House of Commons, Mr. Nutting, Minister of State, Foreign Affairs, said that the licences were granted in accordance with the approved exemptions procedure of the China Committee. He believed that the number was about sixty tractors.

A statement by Mr. Lionel Harper, president of the Agricultural Engineers Association, has emphasised that the embargo on the export of tractors to China has not yet been lifted. The tractor industry, however, Mr. Harper said, would be encouraged by the issue of these licences to at least four manufacturers for small " sample " lots. The plan for exporting increasing quantities of tractors to China was essentially a long-term, or at least a medium-term, proposition. Sample tractors would require to be field-tested in China over a reasonable period. Assuming that they met the demands of the varying and difficult conditions, and that satisfactory financial arrangements could be made, business should flow in fairly substantial volume.

Employment and Unemployment

At the end of February, the number of people in civil employment in Great Britain was 22,950,000. The Ministry of Labour has stated that this was 35,000 less than a month earlier. The principal decreases in employment during February occurred in building and contracting, distribution, and in printing (a consequence of the recent stoppage in London printing establishments).

An analysis of the figures issued by the Ministry shows that in the basic industries there were 3,953,000 people at work in February, or 9000 more than in January. There was a further slight improvement in coal mining manpower, the number of wage-earners on colliery books at the end of February being 704,000, compared with 700,000 at the end of last year. There was also an addition of 2000 during February to the number employed in transport and communication. In the manufacturing industries manpower declined by 17,000 during February to a total of 9,333,000. In the vehicle building industry the employment figure of 1,258,000 was the same as at the end of January ; in the " engineering, metal goods and precision instruments " group the number employed fell by 2000 during February to 2,823,000, but chemicals and metal manufacture each added 1000 to their labour forces during the month.

The latest unemployment figures from the Ministry of Labour show the position on March 12th. Then, there were 265,522 people registered as out of work (1·2 per cent of the total number of employees), compared with 275,628 registered on February 13th. The Ministry says that, in the week ended February 25th, about 65,000 operatives in manufacturing establishments rendering returns were reported to be on short time, losing eleven and a half hours each on the average. On the other hand, in the same week 1,560,000 production workers were doing, on average, eight hours' overtime.

Iron and Steel

British steel production reached a new record during March by averaging 425,800 tons a week. This represented an annual output rate of 22,141,000 tons, compared with a rate of 20,536,000 tons a year earlier. Pig iron production in March averaged 262,000 tons a week, and was thus at an annual output rate of 13,624,000 tons, compared with a rate of 12,516,000 tons in March last year. In the first quarter of this year steel production amounted to 5,413,000 tons.

The Iron and Steel Board says that if this year's estimate of steel production, 21,300,000 tons, is met it will exceed last year's output by about 7½ per cent. Imports by the steel industry are estimated at 600,000 tons, and it is expected that 300,000 tons of reusable material will be available this year. Steel exports for this year are calculated at 3,350,000 tons, which means that, over the year, supplies for the home market from the steel industry should amount to 18,850,000 tons, compared with 17,000,000 tons last year. It is not possible to estimate at all closely the tonnage of finished steel which will be imported directly by consumers this year. Last year it was equivalent to 1,200,000 ingot tons. This year less sheet and tinplate is expected to be imported, but, it is stated, there may be some increases in other products.

Mining Subsidence

In reply to questions in Parliament last Monday, the Minister of Fuel and Power, Mr. Aubrey Jones, said that the Government had reviewed the Turner committee's recommendations on coal mining subsidence in the light of developments since the report on the matter was published in 1949. The Government had concluded that where, as the law now stood, surface interests had no right to compensation when coal mining subsidence occurred, the National Coal Board should be obliged to make good physical damage to land, buildings, service lines and pipes, or make a reasonable payment. The Minister went on to say that the surface interests concerned would include owners of agricultural land and also local authorities. Provision would be made to deal with the problems of drainage authorities, including river boards. Since subsidence damage was part of the cost of winning coal, the Minister added, the Government considered that this cost should be fully reflected in the price of coal. New legislation to give effect to the proposals would be introduced as soon as practicable. The Minister said it was estimated that the cost of the new measure would be about £5,000,000 a year, or sixpence per ton of coal mined.

Continental Engineering News

European Steel Production in 1955

Statistics collected by the United Nations Economic Commission for Europe* show that European crude steel production (including U.S.S.R.) in 1955 totalled 138,883

TABLE I—*Crude Steel Production (in Millions of Metric Tons)*

	1955	1954	Percentage increase
U.S.S.R (total)	45·20	41·00	11
German Federal Republic[1]	21·33	17·43	22
United Kingdom	20·11	18·82	7
France[1]	12·58	10·63	18
Belgium[1]	5·89	5·01	18
Italy[1]	5·40	4·21	28
Czechoslovakia	4·75	4·43	7
Poland	4·50	3·96	13
Luxembourg[1]	3·23	2·83	14
Saar[1]	3·17	2·80	13
German Democratic Republic	2·50	2·34	7
Sweden	2·15	1·86	15
Austria	1·83	1·65	11
Hungary	1·60	1·49	7
Spain	1·20	1·10	9
Netherlands[1]	0·97	0·93	5
Yugoslavia	0·80	0·62	29
Rumania	0·70	0·63	11
Small producers[2]	0·98	0·86	14
Total	138·89	122·60	13
Of which 18 countries[3]	79·63	68·75	16
E.C.S.C. countries	52·57	43·84	20

[1] European Coal and Steel Community (E.C.S.C.).
[2] Under 500,000 metric tons per year: Denmark, Finland, Greece, Norway, Switzerland and Turkey.
[3] Austria, Belgium, Denmark, Finland, France, German Federal Republic, Greece, Italy, Luxembourg, Netherlands, Norway, Saar, Spain, Sweden, Switzerland, Turkey, United Kingdom, and Yugoslavia.

million metric tons, or 13 per cent increase over 1954. It thus again exceeded the previous year's figure, which has been the case in each successive year since 1949, when the 1937 record was surpassed for the first time. The output of each of the major European producers, excepting Rumania, whose production was slightly below the 1953 record, was the best which has yet been achieved. Production figures are shown in the accompanying table.

Crude steel production both in the United States and in Japan was also a record, amounting to nearly 106 million and 10,000,000 tons respectively. Compared with 1954, this constitutes increases of 32 per cent in the United States and 26 per cent in Japan. However, 1954 was a relatively poor year for steel production in the United States, so that the figure of 4 per cent increase over 1953 (a record year) is a better indication of the prevailing trends.

The *ECE Bulletin* also gives the foreign trade figures for the first ten months of 1955, which indicate that during August, September and October exports of finished steel from all the main West European countries were at a higher rate than in the same period in any previous post-war year, except in the case of Austria, where they were slightly down on the 1954 figures. Imports and exports figures are set out in the second table.

TABLE II—*Imports and Exports of Finished Steel*
In thousands of metric tons. Export figures in brackets.

	1954	Jan.-Oct., 1955
Austria	— (504)	— (430)
Belgium/Luxembourg	240 (4428)	237 (4454)
France/Saar	408 (3684)	565 (3949)
German Federal Republic	1788 (2496)	2262 (2166)
Italy	696 —	495 —
Netherlands	1440 (408)	1509 (431)
Sweden	698 —	739 —
Switzerland	624 —	640 —
United Kingdom	372 (2208)	1228 (2136)

The E.C.E. bulletin shows—as might be expected in a period of increasing iron and steel production—that there has been a general rise in the exchanges of steelmaking raw materials during the third quarter of 1955. In the period July-September, 1955, iron ore imports into Belgium/Luxembourg (3·84 million tons), the German Federal Republic (4·36 million tons), Italy (0·31 million tons), and the United Kingdom (3·73 million tons) were higher than in any previous post-war quarter. Swedish exports at 4·95 million tons, were also far higher than in any previous quarter, while French exports at 3·36 million tons, were almost the same as those in the preceding quarter, the best since the war.

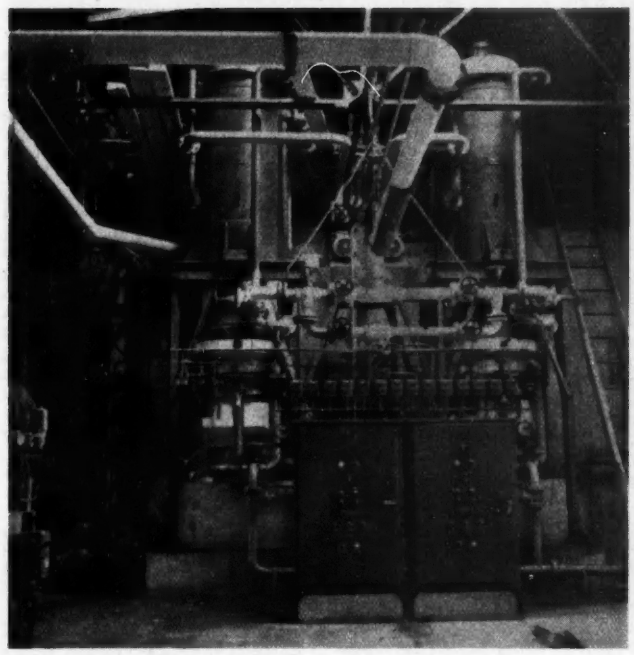
Coke imports into Belgium/Luxembourg (0·91 million tons), France/Saar (1·09 million tons), and Sweden (0·60 million tons), maintained a very high rate, as did the exports from the Federal Republic (2·63 million tons) and those from the United Kingdom (0·5 million tons). Scrap imports into the German Federal Republic (285,000 tons), Italy (489,000 tons), and the United Kingdom (319,000 tons), although less than in the previous quarter, were still at a high level. Exports of scrap from France/Saar at 850,000 tons and from the German Federal Republic at 89,000 tons were in each case well under half the previous quarter's figure.

Western Europe's net imports of iron ore and scrap, which reached an annual rate of 10·0 and 4·3 million tons, respectively, in the first six months of last year, appear to be continuing to rise, showing that Europe is becoming more and more dependent upon overseas supplies.

* *Quarterly Bulletin of Steel Statistics for Europe*, Vol. II, No. 4. Geneva: ECE. Bilingual edition (English-French). Obtainable from H.M. Stationery Office. Price 7s.

Sea-Water Ice Plant

We have received details of an ice-making plant at Port Joinville, on the Isle d'Yeu, where ice is made from sea water for the purpose of preserving fish. Sea-water ice is said to be better for this purpose than fresh-water ice, as the taste of the fish is not affected as it is when ordinary ice is employed.



Fully automatic twin unit for making 20 tons per day of clear tubular ice from sea-water

The plant which has a capacity of 40 tons of ice per day comprises two ammonia compressors, one of "Brissonneau et Lotz," the other of "Loire" manufacture, developing 110,000 k.cal. per hour each, and three vertical shell-and-tube ammonia condensers cooled by sea water. The liquid ammonia is passed to two evaporators which are of the flooded design with a ball valve controlling the level of ammonia. These combined evaporators/liquid separators are built to a patent by Refroidisseur Trépaud, 44, Rue la Boétie, Paris (8*e*). In them, the ammonia is evaporated in vertical tubes, with brine circulating around the tubes guided by helical baffles. The efficiency is such that evaporation can take place at temperatures as high as −12 deg. to −11 deg. Cent., in spite of the fact that sea water freezes below 0 deg. Cent., and an intermediate brine solution is used.

The brine is then passed to the ice-making plant itself which consists of two ice generators of a daily capacity of 10 tons each and one of 20 tons. In this plant, which also was developed by Refroidisseur Trépaud, the brine is pumped over the outside of a nest of tubes, while inside the tubes the sea water to be frozen is circulated by means of a central propeller. In this way, tubular layers of clear ice of 40mm outer diameter are formed, and are allowed to build up to the thickness required, a process which takes 15 minutes to 45 minutes. For discharging the ice, each generator can be opened at the bottom end. By circulating tepid brine instead of cold brine the ice tubes are loosened and drop into a cutter where they are chopped to the required length or broken down into splinters.

Water not frozen in the generators is collected in tanks and pumped through two heat exchangers where it cools the compressed ammonia, and then is passed to the condensers.

Tepid brine for melting out the ice tubes is produced by heat exchange between cold brine and sea water to be frozen. Should the sea water be too cold to enable the brine to be warmed sufficiently, additional heat is supplied by using some of the condenser water, the admission of which is controlled by a thermostat.

The generators operate entirely automatically under all conditions by means of relay-controlled electric motors. Each phase of the cycle is controlled by instruments, for instance, the end of the freezing period is indicated by a contact monometer which registers the pressure build-up of the circulation developed by the propeller. This allows the generators to adapt themselves to changes in the temperature of the water and other variables. One of the ice-making units is shown in the accompanying illustration.

The sea water used in manufacturing the ice is drawn from a small creek in which it is impounded between tides by two dams, and from where it is pumped to a storage tank at the factory. Storage capacity for about 150 tons of ice is provided, the cold room being kept at −5 deg. Cent. by forced circulation of cooled air. An automatic system of conveyors and loaders is employed for transferring ice from the generators into storage, and for loading it into trucks to take it to the harbour which is about a kilometre away.

Hall Acoustics and Stereo-Reverberation

The acoustic requirements of a hall differ in important respects according to whether the hall is to be used for speech or for music. If the reverberation time (defined as the time in which the sound intensity at the point under consideration decreases by 60 decibels after the source has ceased to radiate) exceeds 50 milliseconds, speech tends to become unintelligible. On the other hand, for music to acquire a delicate and full tone the reverberation

time must be longer, the optimum depending upon the nature of the music. Even more important appears to be the diffuseness of the sound, and possibly the fluctuations of the reverberation have also an important effect.

These problems have been investigated at the Philips research laboratories at Eindhoven,* where apparatus for the artificial production of stereo-reverberation has been installed at the Philips Theatre. Similar equipment has been put into permanent use in the Arts and Sciences Hall at The Hague. In principle, this consists of a number of loudspeakers distributed over the auditorium which are supplied from one microphone and amplifier operating through a delay wheel. This is a rotating disc coated on its edge with magnetic sound recording material. One recording head and a number of play-back heads are mounted around the circumference, with an erasing head immediately preceding the recording head. After further amplification, the output of the play-back heads is fed into the loudspeakers. The delay between recording and pick-up, and hence the reverberation time, can be varied by changing the angular position of the play-back heads.

In such a simple arrangement acoustic feedback occurs through the microphone picking up the sounds from the loudspeakers as well as reverberation from the walls. This easily proves troublesome as it may prevent sounds at certain frequencies from decaying altogether. The large number of such peaks precludes their suppression by filters in the microphone channel. It is possible to avoid the difficulty by using electrical feedback from the last play-back head to the recording head, in place of acoustic feedback, or else employ one or more strongly directional (line) microphones. Diffuseness is obtained by connecting the loudspeakers in random sequence to the play-back heads. The listener must always have the impression that the sound comes from the original source, not from the loudspeakers.

Preliminary experiences with stereo-reverberation installations appear to be highly satisfactory. Apart from concert halls, the same principle could be applied to cinemas and broadcasting studios (two large Dutch studios are planned which, it is stated, will be so equipped), and the quality of transmissions to " overspill " audiences could be greatly improved.

* *Philips Technical Review*, Vol. 17, No. 9. March 1956, page 258.

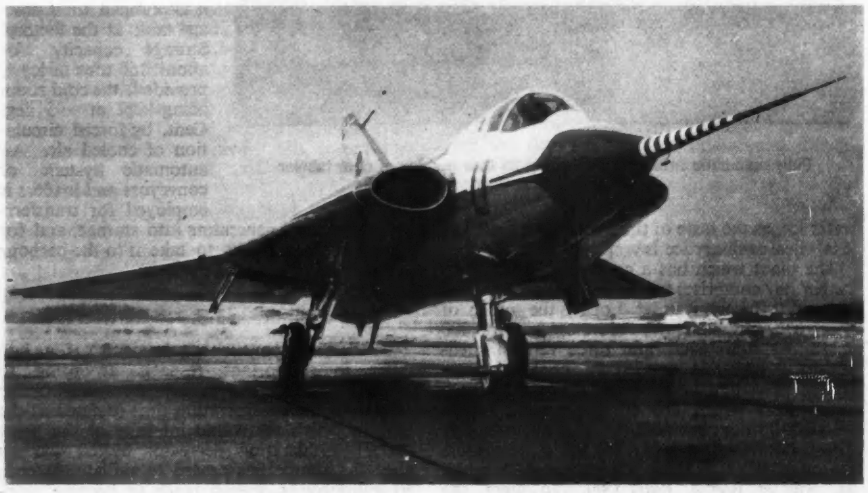
Swedish Jet Fighter

The accompanying illustration shows the SAAB-35 prototype jet fighter, built by Svenska Aeroplan Aktiebolaget, Linköping, which made its first test flight on October 25th last. The aircraft is a supersonic design and is intended to go into service with the Swedish Air Force as the " J35 Draken."

It is a single-seater with " double delta " wings, a configuration developed in Sweden during the last few years and tested with the SAAB-210 research jet aircraft, which made its first flight in January, 1952. It is stated that its shape offers a relatively large space for equipment and fuel, at low weight and low drag at supersonic speeds. The air intakes are built into the inner wings in such a way that the boundary layer air at the nose of the fuselage is led past the air intakes, thus providing a high degree of intake efficiency. Combined elevators and ailerons are fitted to the trailing edges of the wings, replacing the conventional tailplane. The fin also has a delta shape and continues forward to the cockpit in a low spine, containing various control lines and other equipment which is thereby rendered readily accessible. The cockpit is pressurised and is equipped with a fully automatic ejector seat. All flying controls are servo-operated, with " synthetic feel " being applied to the stick and pedals. The main legs of the tricycle landing gear have specially designed shock absorbers, which are shortened during retraction in order to use up less space. A brake parachute is fitted in a container underneath the fin.

The SAAB-35 is powered by a Rolls-Royce " Avon " engine with afterburner, which will be built under licence by Svenska Flygmotor AB. Normally the armament consists of cannons, but rockets or air-to-air guided missiles can also be carried. It is intended to install electronic equipment for all-weather navigation and for flying at very high altitudes.

After further testing by the makers and at the Air Force experimental establishment at Malmslätt, the fighter is to go into quantity production. It will gradually replace the SAAB-29 (the J29 " Flying Barrel "), which was test flown in 1948 and first delivered to the fighter wings in 1951.



The " SAAB-35 " of which the prototype is shown here is of double-delta wing design and powered by a Rolls-Royce " Avon " engine. It is an all-weather fighter for supersonic speeds in level flight

Sweden's Trade in 1955

During last year, Sweden's foreign trade showed big increases in the surplus of imports from the German Federal Republic and the dollar area, while a large increase in exports to the sterling area has occurred. Against an overall figure for imports of Kr.10,305 million (an increase of 12 per cent), there must be set an increase in exports to Kr.8945 million (9 per cent), leaving a trade deficit of Kr.1360 million, as against Kr.996 million in 1954.

The increase in Swedish exports to the sterling area was 14 per cent, a minor decrease being noted for imports. This increased the Swedish sterling trade surplus from Kr.50,000,000 to Kr.350 million. Imports from Germany increased from Kr.859 million in 1954 to Kr.1075 million in 1955, and these accounted for the major portion in the Swedish payments deficit of about Kr.200 million with other E.P.U. countries. Large import surpluses were also registered in the trade with the Netherlands and Belgium, while Swedish-French trade was almost completely balanced, and there were export surpluses with Norway, Denmark, Finland, and Spain.

The trade deficit *vis-a-vis* the dollar area almost doubled to Kr.750 million, a 44 per cent increase in imports being registered above 1954, primarily as the result of the liberalisation of dollar imports introduced in October 1954. Diminished exports to the Soviet Union and Eastern Germany, and increased imports of oil from the Soviet Union and Rumania, resulted in a deficit of Kr.125 million in the East European trade, compared with about Kr.100 million in 1954.

Shipbuilding in Sweden

According to Lloyd's Register, the total tonnage launched by Swedish shipyards during 1955 amounted to 525,814 tons, or nearly 10 per cent of the 5,320,000 tons launched in the whole of the world (excluding the Soviet Union, China and Poland). In 1954 Sweden ranked third among the shipbuilding countries, but according to the present figures it has been surpassed by Japan, while Great Britain and the German Federal Republic retain first and second place. As regards tanker tonnage, Sweden came third after Great Britain and Japan, with 13 per cent or nearly 322,000 tons, out of 2,440,000 tons launched.

Oil Refinery at Cologne

Plans have been announced by Esso A.G., Hamburg, for the largest oil refinery yet to be built in the Federal Republic. It will be situated on the left bank of the Rhine opposite Leverkusen, north of Cologne. A site of 2·5 square kilometres has been obtained from the Cologne municipality and preparatory work is to commence this spring. Construction of the plant itself is to begin next spring, and the first stage, with an annual throughput of 3,000,000 tons, is to be finished in the first half of 1959. When the refinery is completed in 1961, at a total cost of DM.200 million, it will have a throughput of 5,000,000 tons.

The plant will have its own harbour facilities and will include a tank farm of 700,000 cubic metres capacity, which is more than double that of the Hamburg refinery. A pipeline, estimated to cost DM.150–160 million, will connect the refinery with either Wilhelmshaven or Rotterdam. This is to be built jointly with other oil refineries in the Ruhr, which will also be supplied by it. About 40 per cent of the cost is to be born by Esso.

Of the first stage throughput, 50 per cent will be converted into fuel oils of all grades, 18 per cent into petrol or diesel oils, and 26 per cent gas oil, the remainder being gas and losses. This production reflects the increasing demand for fuel oil in Germany, which, excluding fuel for bunkering, increased from 8,000,000 tons two years ago to 10,000,000 tons, and is expected to rise to at least 15,000,000 to 20,000,000 tons by 1965. If other mineral oil products, such as petrol and diesel fuels, are added, the total consumption is likely to treble by 1965. Such estimates are based on an increase in West Germany's energy consumption of at least 25 to 30 per cent during the next decade.

A total of DM.500 million is to be invested by Esso A.G. in the course of the next three to four years. Beside the Cologne refinery and a part of the cost of the pipeline, this will include the building by German yards of six tankers, each of 36.000 tons deadweight. In addition, there will be the cost of increasing the distribution facilities in proportion to the higher output.

Brussels International Fair

The thirtieth International Fair will be held in Brussels from April 28 to May 13, 1956. The fair will occupy an area of 111,000 square metres, which is the same as last year, even though rebuilding is at present going on at the site in preparation for the exhibition scheduled for 1958. Hall 11, which formed a connection between halls 3 and 4, on the one side, and halls 5 and 6 on the other, has been demolished in order to make room for a building of 22,000 square metres. Only the left wing of the new structure will be in occupation at the time of the fair, when it will house the sections " Industrial Furniture," " Sewing Machines," " Food Machinery and Kitchen Equipment," and part of the section on " Heating." Halls 6A, 7 and 8 will be in use for the last time. The open-air exhibition terrace will be extended.

Work of the U.S. Atomic Energy Commission

BY OUR AMERICAN EDITOR

No. I

THE nineteenth biannual report to Congress of the U.S. Atomic Energy Commission (A.E.C) covers the International Conference on the Peaceful Uses of Atomic Energy which was held in Geneva last August. There were many other noteworthy developments in the "Atoms-for-Peace" programme of the United States and co-operating nations during the past six months. The growing pace of action required the creation of a new Division of International Affairs to provide organisational arrangements to help handle the Commission's part in the programme. Other events during this period included the completion of co-operative agreements between the United States and twenty-two other countries on peaceful applications of atomic energy; a steadily increasing international exchange of technical information on various phases of atomic developments; progress in the establishment of an International Atomic Energy Agency; and announcement by the Commission of a price for enriched uranium leased to co-operating nations under bilateral agreements together with sales prices for normal uranium and heavy water. While moving forward with the international "Atoms-for-Peace" programme, the Commission continued its domestic activities at an accelerating pace. The pattern was formed for further A.E.C. provisions to encourage private enterprise in the development of an atomic energy industry, and for applying the necessary regulations and licensing arrangements under the Atomic Energy Act of 1954. A constant flow of applications for access permits from a wide variety of industries, trades and professions testified to the interest of private organisations and individuals in obtaining access to restricted data on civilian uses. An accelerated programme of reviewing Commission reports and other papers useful in civilian applications and of declassifying or downgrading whenever possible was entered upon. At the same time the programme for publishing material available to industries and individuals in the civilian application programme was greatly stepped up. Seminars and other meetings were held with representatives of companies interested in getting into the processing or production of selected atomic energy materials.

Raw Materials

Domestic uranium ore and concentrate production continued to rise, maintaining the status of the United States as one of the leading uranium producers. Production will increase further with the expansion of the present mills, the completion of new facilities now under construction, and the construction of additional mills upon completion of contracts now under negotiation. During the last six months of 1955 the number of producing mines increased to an estimated 925, as compared with approximately 850 as of June, 1955. Although the rate of increase in the number of producing mines slowed considerably, the production rate from existing mines continued its sharp increase. The uranium producing areas were extended by the first commercial deposits of uranium in Oregon and Texas, and new areas of potential production were developed in North and South Dakota and Alaska.

Ore production is now in excess of current processing capacity, but additional mill facilities are being provided at a rapid rate. Except for the Commission's mill at Monticello, Utah, all expansions and new mills are privately financed. Stockpiles of ore in excess of normal plant requirements are found only at sites where new mills have just been completed or at sites where new mills are either planned or under construction. On the average the processing plants on the Colorado Plateau were operating at slightly above their rated capacities, accounting for the record levels of production reached during this period.

Increases in domestic ore reserves, both on and off the Colorado Plateau, again reflected the greatly expanded exploration activity of private industry. This has permitted an orientation of Government exploration activities performed by the Commission and the U.S. Geological Survey to appraise the results of private exploration and the execution of basic geologic programmes. Private interests have now assumed virtually all drilling activities in connection with uranium exploration and development. Government drilling, which is restricted to the support of geologic investigations, amounted to less than 200,000ft in the last half of 1955 in comparison with 358,000ft in the first half. The first commercial deposits of uranium were found in Oregon; significant reserves are being developed in the Dakota plains lignite fields, and a considerable tonnage of uranium ore has been found in Karnes County, Texas. Recent preliminary investigations indicate the possibility of an important uranium deposit on Prince of Wales Island, in South-Eastern Alaska. A major discovery was made in the Ambrosia Lake area of McKinley County, New Mexico, during the period. Preliminary results of drilling by private companies indicate that the reserves in the area may amount to several million tons.

Production

The production of the various special nuclear materials during the last half of 1955 equalled or exceeded the quantities produced during the first half of the year. Construction of the gaseous diffusion facilities at Portsmouth, Ohio, is ahead of schedule as the last building is nearing completion. The construction of additional feed processing facilities which began last March at Fernald, Ohio, St. Louis, Missouri, and Paducah, Kentucky, is proceeding.

On October 27, 1955, the Commission announced that it would accept proposals from industrial concerns for the manufacture of uranium feed material. The deadline for the submission of proposals is October 1, 1956. Specifically, the Commission is interested in receiving proposals from qualified firms to process, over a five-year period, uranium ores or concentrates to either uranium trioxide, uranium tetrafluoride, or uranium hexafluoride, with deliveries to begin about April 1, 1959. The Commission will consider proposals for any production rate up to a maximum of 5000 tons U_3O_8 equivalent per year. The proposals may be based on arrangements whereby the U_3O_8 concentrates are supplied by the Commission and refined salts returned. Alternatively, the Commission will consider proposals for the direct purchase of the refined products from a company having or obtaining its own supply of uranium ores or concentrates. In the latter connection the Commission will consider appropriate modifications in contracts now in effect between the A.E.C. and suppliers of uranium concentrates. During November a "Formal Inquiry for Purchase of Uranium Products from Private Industry" was sent to about 600 companies. These companies and other interested persons were invited to a general orientation meeting designed to present the scope and magnitude of the undertaking. Proper security clearances were required for attendance at the sessions. More than 100 persons representing seventy companies attended the meeting in Washington on December 8th.

Reactor Development

The programme of developing reactors for industrial and military power and for naval and aircraft propulsion made significant progress during the last six months of 1955 and expenditures for this period totalled approximately 62·3 million dollars. In September the Commission issued its second invitation under the power demonstration reactor programme for proposals to develop, design, construct and operate power reactors ranging from 5MW to 40MW of electrical capacity to demonstrate the practical value of such units for commercial use. Emphasis continued on the development of advanced power reactor technology through a number of experimental reactor projects. In this programme four reactors are under construction, three of which are scheduled to be completed in calendar year 1956, and the fourth in 1957. The construction of a fifth is scheduled to start in 1956. In addition four new small reactor experiments are in progress to explore other promising reactor concepts.

During the last six months of 1955 substantial progress was made in the construction of the first American large-scale 60MW civilian nuclear power station — the pressurised water reactor (PWR) at Shippingport, Pennsylvania. The Westinghouse Electric Corporation is developing, designing and fabricating the nuclear portion of the PWR for the A.E.C. The Duquesne Light Company, of Pittsburgh, is building the conventional portion of the plant and will

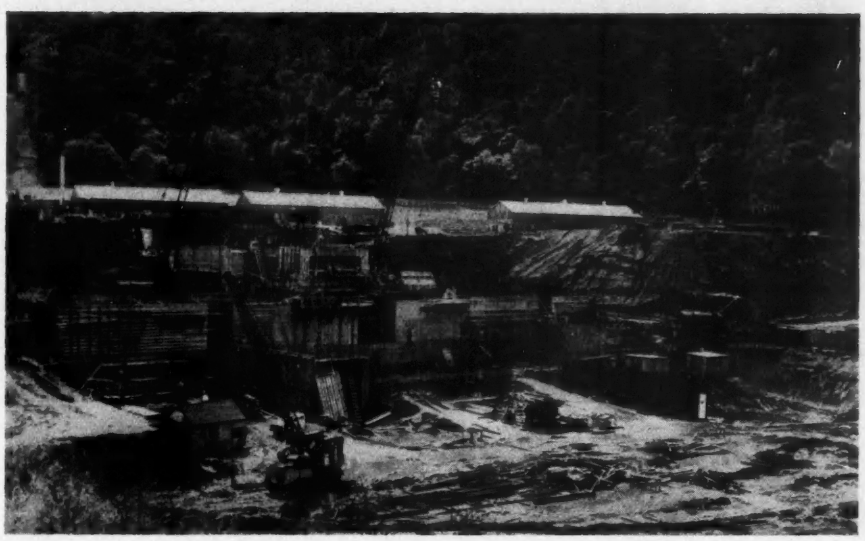


Fig. 1—Start of concrete placement for the reactor foundation at the 60MW civilian nuclear power station at Shippingport, Pennsylvania

operate the entire plant when it is complete. Excavation was completed in July. The first concrete for the reactor foundation was poured in August and some 15,000 cubic yards of concrete were in place by November 1st. The erection of the steel structures to house the nuclear portion was begun in November by the Pittsburgh-Des Moines Steel Company under a fixed price sub-contract to Westinghouse. The reactor vessel, which will contain the core of uranium fuel, is now being constructed by Combustion Engineering, Incorporated, in its Chattanooga shops. The plate in this vessel, 8½in thick, including a ¼in cladding of stainless steel, was rolled by the Lukens Steel Company, of Coatesville, Pennsylvania. Two steam generators are being constructed by the Babcock and Wilcox Company and two by the Foster Wheeler Corporation. All other major components are on order with the first deliveries now being made.

The Argonne National Laboratory continued its work on the development of boiling water reactors. This design of reactor differs from the pressurised water reactor in that steam generation is allowed to take place in the reactor pressure vessel at the core itself. The development of the technology of the boiling reactor involved a series of reactor tests known as the Borax experiments, the first of which (Borax I) was operated at the National Reactor Testing Station in Idaho in 1953. The second experiment (Borax II) was conducted during the winter of 1954–55 to study the steady state and transient characteristics of a boiling reactor and to define the limits of stable operation as a function of variables such as pressure and specific power. The Borax III experiment used the same reactor vessel as Borax II, but incorporated a new core to produce greater thermal power. In addition, a 3·5MW turbo-generator was installed (Fig. 2). This reactor became critical on June 9, 1955, and on July 17, 1955, the town of Arco, Idaho, was connected by transmission line to the Borax power plant. For an hour and five minutes electricity exclusively from this point was furnished to Arco. The next step in the development of the boiling reactor project is the construction and operation of the experimental boiling water reactor power plant (EBWR), which is designed to produce 20MW of heat and 5MW of electricity. The EBWR is now under construction at the Argonne National Laboratory and is expected to be generating power during the latter part of this year. The boiling reactor, for which the Commonwealth Edison Company and associates have requested a licence, would carry this design of atomic power plant to the full-scale stage.

A sodium-cooled, graphite-moderated experimental reactor (SRE) of 20MW heat capacity is being built by Atomics International, a division of North American Aviation, Incorporated, at Santa Susana, California (Fig. 3). The engineering test building, to be used for experimental tests and for assembling the fuel elements, moderator, and other reactor components, was erected by the Dudley Steel Company and is now occupied by Atomics International. Many of the large components of the reactor assembly are now ready for installation. The core cavity liner and the outer tank were completed and assembled. The inner core tank was completed for assembly in November, and the sodium pumps and the sodium heat exchangers are now being assembled for installation. The final assembly of all components for the SRE is scheduled for April of this year and full power operation is anticipated by July or August. Meanwhile engineers are being trained for reactor operation, and experimental testing of reactor components is being continued. The original plans did not provide for generating steam or electricity with the SRE. However, all public and private utilities within transmission distance were queried. A contract is now being negotiated with the Southern California Edison Company, under which it would, without cost to the Government, install and operate a turbo-generator plant including heat exchangers and other electrical equipment. The company would pay the Commission 45 cents per million B.Th.U. for the heat used to generate electricity, and has agreed to share with public power groups the information developed in the installation and operation of the generating equipment. The Commission has accepted for negotiation a "Power Demonstration Reactor Programme" proposal from the Consumers Public Power District of Columbus, Nebraska, for the construction and operation of a large sodium-graphite power reactor. The fabrication of this reactor is expressly contingent upon the successful operation of the sodium reactor experiment. Atomics International completed a preliminary design study for a 75MW electrical plant which takes full advantage of the experimental and fabrication experience gained with the SRE. This study is the basis on which the Consumers Public Power District submitted its proposal.

Numerous experimental tests were conducted at the first experimental breeder reactor (EBR–1) to evaluate this system further. Fuel elements of plutonium were fabricated for EBR–1 and will be in use in the near future. The plutonium loading will give valuable technical information on breeding and control behaviour, and will provide other nuclear engineering data. The development of the second experimental breeder reactor (EBR–2) is now under way. The plant will be sodium cooled, and will generate 62·5MW of heat and produce 15MW of electricity. A one-half scale, non-nuclear mechanical model of the EBR–2 was built at the Argonne National Laboratory. The model operated successfully and demonstrated the technical feasibility of operating mechanisms under sodium at temperatures of 700 deg. Fah. The hydraulic characteristics of the sodium-coolant system and the performance and reliability of the electro-magnetic coolant pumps are being determined. The construction of the EBR–2 is scheduled to start this year at the National Reactor Testing Station. The reactor is due to be in operation at full power in 1959.

The construction of a zero power fast critical assembly was completed at the Idaho testing station. This facility began operation in October and will be used to provide the accurate data necessary for the detailed design of the core of EBR–2. A facility for the development and experimental fabrication of fuel elements containing plutonium is an essential requirement for the development of fast breeder reactor power plants, and the construction of such a facility at Argonne National Laboratory is proceeding. A fast breeder reactor concept of advanced design is being investigated by the Los Alamos Scientific Laboratory; the reactor would use molten plutonium as fuel and sodium as coolant. Its potential advantages include the elimination of fuel element fabrication, a greater burn-up, an improved heat transfer characteristic and a high breeding ratio.

A homogeneous reactor is one in which the fuel material is evenly mixed throughout the moderator. Aqueous homogeneous reactors are attractive for the production of power because the fluid state of the fuel and the unique quality of heavy water as a moderator make possible such desirable characteristics as high power density and low fuel inventory, continuous removal of fission products and radiation damage products, high degree of nuclear stability, elimination of fuel element fabrication, elimination of control rods, and simple mechanical design. Aqueous homogeneous reactors are classified as one region—if the fissionable and fertile materials are uniformly mixed—or two region—if the fissionable material is in a core, surrounded by a blanket of fertile material in a shell. They are also classified as circulating fuel or boiling, depending upon the method of removing heat. The primary responsibility for the aqueous homogeneous reactor programme has been assigned to the Oak Ridge National Laboratory, where the homogeneous reactor experiment No. 1 (HRE–1) was designed and constructed, and in 1954 dismantled after two years of successful operation. The programme is now focused on the homogeneous reactor experiment No. 2 (HRE–2), a two-region system. The objectives of the HRE–2 are to demonstrate that a homogeneous reactor of moderate size can be operated with the continuity required of a power plant; to establish the reliability of engineering materials and components of a size which can be adapted to full-scale power plants; to evaluate equipment modifications leading to simplifications and economy; to test simplified maintenance procedures, particularly maintenance under water, and to develop and test methods for the continuous removal of fission and corrosion contaminants. The construction of the HRE-2 is scheduled for completion early this year. Following the usual mechanical and leak testing, the reactor will be put into operation with only heavy water in the blanket system. The fuel will be in a dilute solution of uranyl sulphate (about 90 per cent uranium 235) in heavy water. Operation is expected to continue with this combination for a minimum of six months to establish the reliability of operation and to test the effectiveness of continuous chemical extraction processes. For the latter purpose, a chemical pilot plant is attached directly to the reactor. During this period the power output of the reactor probably will not exceed 10MW of heat. Later, a modification for operation at higher power is contemplated. In further testing it is planned to use a blanket consisting of a suspension of thorium oxide in heavy water. The Pennsylvania Power and Light Company and the

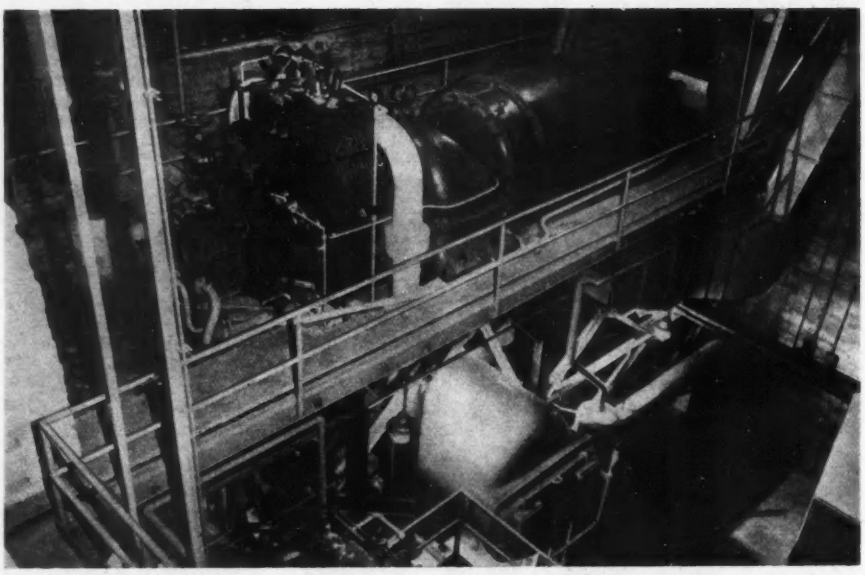
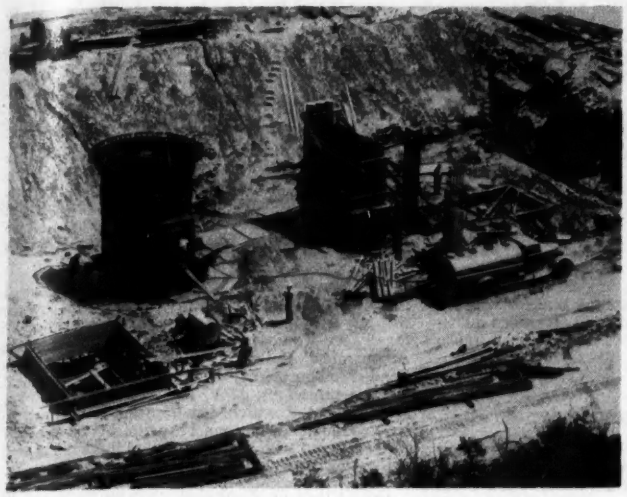
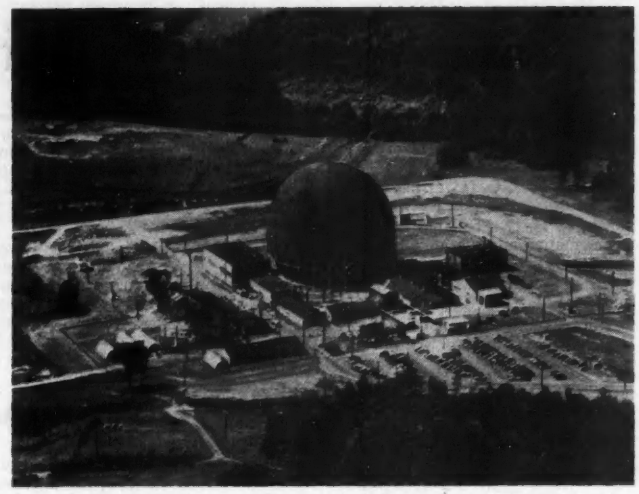


Fig. 2—3·5MW turbo-generator installation at the National Reactor Testing Station used in conjunction with the "Borax III" experiment to supply electricity to the town of Arco, Idaho





Figs. 3 and 4—(Left) Early stage of construction of the sodium-cooled graphite-moderated experimental reactor (SRE) of 20MW thermal capacity at Santa Susana, California. (Right) The submarine intermediate reactor facility at West Milton, New York, with the sphere housing the land-based prototype nuclear power plant for the U.S.S. "Seawolf"

Westinghouse Electric Corporation have notified the Commission that they are working on the development of a full-scale homogeneous atomic power plant which will utilise technology to be developed in the Oak Ridge programme.

In addition to the programme at the Oak Ridge National Laboratory, work on the development of aqueous homogeneous reactors using uranyl phosphate solution and a different mechanical arrangement was undertaken at the Los Alamos Scientific Laboratory. The present effort is directed toward two concepts : the first, the Los Alamos power reactor experiment (LAPRE) No. 1, will employ a circulating pump ; the second, the LAPRE No. 2, will depend on natural convection to circulate the fuel. No. 1 will generate fairly-high-pressure steam and have a thermal output of 2MW. No. 2 will produce a lower pressure steam and have a thermal output of about 1·3MW ; no electricity will be generated. Both of these power reactor experiments are expected to be critical early this year. The reactors involved are of the "Test tube" type, so-called because of the tall cylindrical pressure vessel which contains not only the fuel solution but also the heat exchanger or boiler for the generation of steam. Thus, circulation of the highly radioactive fuel solution outside the pressure vessel is avoided.

The Commission began negotiations with Atomics International of Downey, California, to undertake jointly the sponsorship of an organic-moderated reactor experiment (OMRE) to be conducted at the National Reactor Testing station. The experiment, using the hydro-carbon diphenyl as moderator-coolant, will carry forward research done for the Commission by North American Aviation. The use of organic compounds as reactor moderators and coolants has several potential advantages—low induced radioactivity, low corrosion of fuel elements, and high boiling point which makes high temperature systems possible. The present experiment is designed to simulate conditions of heat transfer, temperature and coolant flow contemplated for a practical power reactor.

A reactor using a molten metal as a carrier for uranium is believed capable of operating at high temperatures and relatively low pressures. The temperatures may be high enough so that the steam conditions are comparable to those in modern conventional generating plants. For several years the Brookhaven National Laboratory has conducted fundamental research on the application of this concept to practical reactor systems. A technical team under the direction of the Babcock and Wilcox Company completed a study of the Brookhaven National Laboratory data and calculations as applied to a reactor concept using graphite as moderator and a uranium solution in liquid bismuth as fuel. The study concluded that "the wide flexibility in design and the economic potentialities of the liquid metal-fuelled reactor (LMFR) concept justify efforts to conduct aggressively the necessary research and development required to bring a full-scale plant into existence." The construction and test operation of a small reactor experiment to explore this concept is now being considered. Two tables summarising certain data relating to the major power reactor experiments and power reactor prototype plants of the A.E.C. will be published next week in an appendix to this article.

Naval Reactors

The objective of the naval reactors programme is the development of a group of naval nuclear power plants in a wide range of power ratings. This group consists of a series of reactors ranging from 3000 to 40,000 s.h.p. which can be used in single or in multiple units to power new naval ships from small submarines to the largest aircraft carriers. The first naval reactors programme consisted of two projects—the submarine thermal reactor and the submarine intermediate reactor. Two more projects for submarine application, the submarine advanced reactor (SAR) and the submarine reactor small (SRS), and a project for surface ship application, the large ship reactor (LSR), have been added.

Work has begun on modifications to the prototype submarine thermal reactor (STR), Mark I, at the National Reactor Testing Station in Idaho to change it to a test facility for investigating new developments in technology, design, and operation of improved water-cooled nuclear power plants. This work is being performed by the Westinghouse Electric Corporation and the Electric Boat Division of the General Dynamics Corporation. While this work is being done, the prototype plant is being refuelled after two and a half years of operation. The U.S.S. "Nautilus," powered by the submarine thermal reactor, Mark II, has steamed in excess of 25,000 miles during a large portion of which it was totally submerged. The "Nautilus" also cruised, submerged, from New London, Connecticut, to San Juan, Puerto Rico, a distance of more than 1300 miles, in eighty-four hours at an average speed of about 16 knots. The reactor continued to operate satisfactorily. The submarine intermediate reactor (SIR), Mark A, the land-based prototype power plant for the submarine "Seawolf," is being test operated for the A.E.C. at West Milton, New York (Fig. 4), by the General Electric Company. The SIR Mark B, which will power the submarine is under construction by the same company at the Knolls Atomic Power Laboratory in Schenectady, New York. The submarine, which was launched in July, is being fitted out at the Electric Boat Division at Groton, Connecticut. General Electric is also continuing to generate electricity from surplus steam from the Mark A plant with the turbo-generator installed and operated by the company at no cost to the Government. Work on the submarine advanced reactor (SAR) continued at the Knolls Atomic Power Laboratory. Earth was moved at West Milton in preparation of the site for construction of test facilities for the prototype of this nuclear propulsion plant. This prototype will be constructed in the area adjacent to the submarine intermediate reactor, Mark A. On July 15, the A.E.C. contracted with Combustion Engineering, Incorporated, for design and development work on the submarine reactor small project.

Design and development work on the large ship reactor (LSR) continued at the Bettis plant at Pittsburgh by the Westinghouse Electric Corporation under A.E.C. contract. The construction of the prototype for this project will commence in the spring at the National Reactor Testing station in Idaho. A contract for the architect engineering work for the prototype was awarded to Arthur G. McKee and Co., of Cleveland, Ohio. The Newport News Shipbuilding and Dry Dock Company was awarded a contract to produce the design of the special shipboard aspects of the prototype plant.

(*To be continued*)

Commercial Atomic Power Equipment Department of General Electric

The General Electric Company, of Schenectady, New York, has announced plans to establish headquarters in San Jose, California, for its Atomic Power Equipment Department, which, by the end of 1956, will employ more than 500 persons. The new atomic department, now temporarily situated in Schenectady, New York, was established in March, 1955, as part of the company's Atomic Products Division. It was organised for designing, developing, manufacturing, and marketing atomic equipment for commercial peacetime uses. Its products include power reactors, research and test reactors, fuel elements, instrumentation and control systems equipment, and reactor auxiliaries and components. Present plans call for the completion of the transfer of the key personnel and facilities of the Atomic Power Equipment Department to San Jose by the end of this year. In December the department announced the "optioning" of approximately 1600 acres of land for atomic laboratory to be situated about 20 miles from San Jose. Dedicated to the promotion of the peaceful uses of atomic energy, the proposed atomic laboratory will support the company's commercial facility at San Jose. The initial facilities of the laboratory will include a radioactive materials component, a critical experimental facility, and a boiling-water reactor pilot plant, which will be used to test various components, materials and operating techniques in atomic energy. The Atomic Power Equipment Department is financed by the firm, while the other components of the company's Atomic Products Division operate under Government contract.

Personal and Business

Appointments

PROFESSOR E. L. HIRST has been elected president of the Chemical Society.

MR. W. B. H. GALLWEY has been appointed chairman of British Acheson Electrodes, Ltd., Sheffield.

MR. C. H. G. FOAN has been appointed resident representative, in the Middle East, of F. Perkins, Ltd.

MR. BERTRAM FLEMING has been appointed works engineer at the Hirwaun, South Wales, factory of Dunlop, Ltd.

THE GENERAL ELECTRIC COMPANY, Ltd., announces the appointment of Mr. F. H. Farthing as manager of the Sussex area.

MR. G. G. DEAKIN has been appointed marketing manager of Caterpillar Tractor Company, Ltd., Desford, Leicester.

WAILES DOVE BITUMASTIC, Ltd., Hebburn, Co. Durham, states that Mr. T. Adamson, chief chemist, has been appointed a director.

MR. ERNEST NORTON has been appointed a director of Yarrow and Co., Ltd. He will be engaged primarily on research and development work.

MR. LIONEL HARPER, managing director of Massey-Harris-Ferguson, Ltd., has been elected president of the Agricultural Engineers' Association.

MR. M. H. L. LEWIS has been appointed a director of Crompton Parkinson, Ltd. Mr. Michael Parkinson has been appointed an executive director.

NEWALL GROUP SALES, Ltd., Old Fletton, Peterborough, has announced the appointment of Mr. W. F. Scott as sales representative for Scotland.

SIR BEN LOCKSPEISER, F.R.S., has joined the board of Tube Investments, Ltd., and has been appointed scientific adviser to the Tube Investments group.

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., states that Mr. R. Craig Wood has been appointed managing director of The Hotpoint Appliance Company, Ltd.

GROUP CAPTAIN E. A. WHITELEY has been appointed a director and general manager of the Bristol Aeroplane Company (Australia) Proprietary, Ltd.

MR. D. K. COUTTS has been appointed manager of the technical office of the Mond Nickel Company, Ltd., in Bombay, in succession to the late Mr. J. McNeil.

THE CENTRAL ELECTRICITY AUTHORITY announces the appointment of Mr. W. H. Foster, A.M.I.E.E., as generation engineer (operation) in the London division.

SIR MILES THOMAS has joined the board of Monsanto Chemicals, Ltd., and is shortly to become chairman of the company in succession to Mr. E. A. O'Neal, Jr.

THE BRITISH THOMSON-HOUSTON COMPANY, Ltd., Rugby, has announced the appointment of Mr. J. G. Boddy as manager of the turbine contracts department.

MR. E. A. LANGRIDGE has been appointed diesel traction assistant (modernisation) to the chief mechanical and electrical engineer, British Railways (London Midland Region), Derby.

DUNLOP, Ltd., announces the appointment of Mr. E. A. Murphy as director of research in its central research division. Mr. H. Trevaskis has been appointed director of development.

HOLMAN, MICHELL AND CO., Ltd., St. Helens, Lancs, states that Mr. T. Denny, the general sales manager, and Mr. J. C. Macgregor have been appointed directors. Mr. E. Saxon has been appointed secretary of the company.

JAGUAR CARS, Ltd., Coventry, announces the following appointments :—Mr. J. Silver, production director ; Mr. W. E. Orr, works director ; Miss Alice Fenton, home sales director ; Mr. F. R. W. England, service director.

THE MINISTER OF SUPPLY has appointed Mr. E. S. Jackson to be director-general, atomic weapons. This is a new post which has been established following the retirement of Lieut.-General Sir Frederick Morgan as controller of atomic weapons.

THE LORD PRESIDENT OF THE COUNCIL has appointed Professor F. H. Garner, M.I.Mech.E., to be chairman of the Water Pollution Research Board, in succession to Professor D. M. Newitt. Professor Garner is director of the engineering department at Birmingham University.

THE COOPER ROLLER BEARINGS COMPANY, Ltd., King's Lynn, announces the following appointments of district engineers : Mr. E. W. Edwards, 164, Icknield Way, Letchworth, Herts ; Mr. C. Lynn Harris, 193, King George V Drive, Heath, Cardiff ; Mr. H. Miller, 61, Cecil Street, Glasgow, W.2.

MR. J. E. SMITH has been appointed deputy managing director of the North Eastern Marine Engineering Company, Ltd., as from May 1st, on which day he will resign from the board of Richardsons, Westgarth (Hartlepool), Ltd. Mr. R. E. Mate succeeds him as general works manager and a director of the latter company.

ARMSTRONG WHITWORTH (METAL INDUSTRIES), Ltd., and JARROW METAL INDUSTRIES, Ltd., state that Mr. R. H. Phillips, secretary and chief accountant, has been appointed a director of both companies. Mr. E. Jarvis has been appointed industrial accountant, and Mr. J. Lamb, head office accountant.

Business Announcements

FERODO, Ltd., states that its Birmingham depot has been moved to new premises at 111/119, New Town Row, Birmingham, 6 (telephone, Aston Cross 1762).

THE ELECTRICAL ASSOCIATION FOR WOMEN has moved to new headquarters at 25, Foubert's Place, London, W.1 (telephone, Gerrard 5212).

AUTOMOTIVE PRODUCTS COMPANY, Ltd., states that the Lockheed Industrial Hydraulics Division has been transferred to Shaw Road, Speke, Liverpool, 19 (telephone, Hunts Cross 2121).

THE PENINSULAR AND ORIENTAL STEAM NAVIGATION COMPANY has announced that Mr. George Denholm, who joined the company as assistant naval architect in 1919 and was appointed naval architect in 1949, has retired.

CONSTRUCTION MACHINERY, Ltd., is the new title of the company hitherto known as Galion (Great Britain), Ltd. Its address is Thornes Moor Road, Wakefield (telephone, Wakefield 4702). The motor graders built by the firm will in future be known as "Wakefield" graders, the distributor for Great Britain and Eire being Jack Olding and Co., Ltd., Hatfield, Herts.

Contracts

THE LOEWY ENGINEERING COMPANY, Ltd., Bournemouth, has secured an order from the Patent Shaft and Axletree Company, Ltd., Wednesbury, South Staffs, for a complete blooming and slabbing mill and a plate mill, worth over £1,500,000, to be delivered by mid-1958.

BRITISH INSULATED CALLENDER'S CONSTRUCTION COMPANY, Ltd., has been instructed by Sir Alexander Gibb and Partners to supply and supervise the installation of an electrical network for the new weapons range at Maralinga, in the South Australian desert. The work in Australia will be carried out in collaboration with British Insulated Callender's Cables (Australia) Pty., Ltd.

DAVY AND UNITED ENGINEERING COMPANY, Ltd., has received an order for rolling mill auxiliary equipment to the value of nearly £1,250,000, from John Summers and Sons, Ltd., for an extensive modification scheme at the Shotton Works, near Chester. In all, over 4000 tons of new machinery will be supplied. Davy and United Engineering Company, Ltd., has also received a further order for rolling mill auxiliary equipment, amounting to nearly £5,000,000 in value, from Dorman Long (Steel), Ltd. The equipment ordered is required for the Lackenby works and comprises two reciprocating primary cooling banks, complete with pull-on-and-off gear, approach and run-out roller tables, and a scrap transfer bank.

RECENT contracts placed by the North Eastern Region of British Railways include the following :—Thackley old and new tunnels, part relining, pointing and grouting, &c., Wellerman Brothers, Ltd.; York depot accommodation, alterations and additions, W. Birch and Sons, Ltd.; Grimethorpe, Bridge 25, renewal of existing superstructure and provision of additional span, Harbour and General Works, Ltd.; Darlington locomotive works, one 30-ton electric overhead crane, Herbert Morris, Ltd.; Low Moor M.P.D., repair of mechanical coaling plant, Mitchell Engineering, Ltd.; Darlington diesel multiple-unit depot, supply and fabrication of steelwork, Cleveland Bridge and Engineering Company, Ltd.; Nostell North Junction, demolition of overbridges Nos. 40 and 47, Demolition and Construction Company, Ltd.; Hunslet East, provision of embankment for tip, William Jones, Ltd.; Hull, Springhead motive power depot, installation of electric lighting, Albert Innes, Ltd.; York goods shed, installation of supply cables, Enfield Cables, Ltd.

Miscellanea

INTERNAL COMBUSTION ENGINE EXPORTS.—We are informed by the British Internal Combustion Engine Manufacturers' Association that the direct exports of engines and parts in 1955 at £29,646,409 was 12 per cent more in value than in 1954, and that the horsepower turnover for these years was 1,708,616 and 1,554,135 respectively.

BOUNDARY LAYER CONTROL.—A delta-winged Avro 707A research aircraft is to be lent by the Ministry of Supply to the Australian Department of Supply for work on boundary layer control at the Aeronautical Research Laboratories, Fishermen's Bend, Melbourne. It is at present being prepared for this project by A. V. Roe and Co., Ltd. The Aeronautical Research Laboratories are known to have conducted wind tunnel experiments on wings of 50 deg. sweep with the intention of suppressing stall at the wing tips by the use of air jets.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—At a meeting of the Institution of Engineers and Shipbuilders in Scotland, held on April 10th, W. Lochridge read his paper "Mechanization in Fishing Vessels." Reference is made to a previous paper which described the design of "Fairfree" and to more recent developments, such as the French trawler "Mabrouk," which was converted for quick-freezing of unfilleted fish. Early filleting machines tested on "Fairfree," it is stated, have been succeeded by a new design and the fish-meal plant has also been improved.

CATIONIC AND NONIONIC CHEMICAL PLANT.—Armour and Co., Ltd., Lindsey Street, Smithfield, London, E.C.1, announces that a plant to produce cationic and nonionic chemicals has been built at Littleborough, near Rochdale, Lancashire, and is operated by Hess Products, Ltd. Among the chemicals produced are : armeens, used in the textile and petroleum industries, for corrosion inhibition, for pigment treatment and in surface coatings ; armacs used as flotation agents for certain ores and polish formulations ; duomeens used as anti-stripping agents in road-making, in moisture proofing of masonry, in curing epoxy resins, in primer paints and in the metal working industry, and arquads used in textile and laundry applications, in the paper and rubber industries and as anti-statics for resins and fabrics.

BRIGHT NICKEL PLATING.—An improved bright nickel process, "Nimax," has been introduced by W. Canning and Co., Ltd., Birmingham. The makers state that for this process the solution is simple to maintain, requiring the use of a single addition agent, known as "Sylax," for the maintenance of both brightening and levelling properties. The process is suitable for iron, steel, brass, copper and other common metals, including zinc-base die cast alloys (after copper plating). We are informed that the new nickel process under prolonged tests has produced deposits having a ductility consistently over 12 per cent elongation combined with a comparatively low internal stress. The solution is used in rubber-lined bright nickel plating equipment and is operated at a temperature of 120 deg. to 130 deg. Fah. at a current density of 36A to 60A per square foot. Its comparatively high operating pH value of 4 to 4·5 minimises dissolution of any exposed unplated metal and reduces to a minimum any subsequent metallic contamination of the solution.

ASSOCIATION OF ENGINEERING DISTRIBUTORS, LTD.—At a recent luncheon of the council of the Association of Engineering Distributors, Ltd., in London, the guest speaker was Mr. J. Orwig Jones, of Edward G. Herbert, Ltd. In introducing the speaker, Mr. T. W. McConnell, the president of the Association, said that to invite a manufacturer to address the council after its luncheon was in keeping with one of the objects of the Association in promoting good relationships between makers and distributors of engineering equipment. Mr. Jones spoke at some length on the difficulties and problems of price maintenance, which, he pointed out, was essential to the future wellbeing of both manufacturers and merchants alike. He also dealt with the ways in which greater efficiency on the part of distributors in servicing machines for minor faults, and in ensuring that operational instruction sheets accompanied each machine sold, could reduce the calls on manufacturers service engineers. The points raised by Mr. Jones were discussed at some length by the council members, who emphasised that a greater degree of co-operation was required from manufacturers to ensure price maintenance, and it was pointed out that certain British machine makers were notorious for their poor instruction sheets and the inadequacy of their spare parts lists.

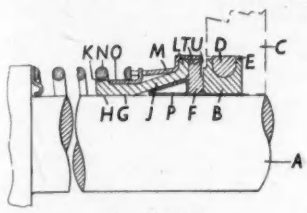
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

POWER TRANSMISSION

744,029. November 3, 1953.—SEALS FOR ROTATING SHAFTS, Carrier Engineering Company, Ltd., 24, Buckingham Gate, London, S.W.1.

The invention relates particularly to a seal for use with a rotating shaft in a stationary housing to prevent leakage of fluids into or out of the housing. Referring to the drawing it will be seen that a shaft *A* is surrounded by a stationary seat or seal member *B*. This seat member *B* is held against rotation and sealed in the cover plate *C* by an O ring *D*. Heat dissipation and squareness are obtained by allowing the seat to bottom solidly in the cover plate counterbore *E*.



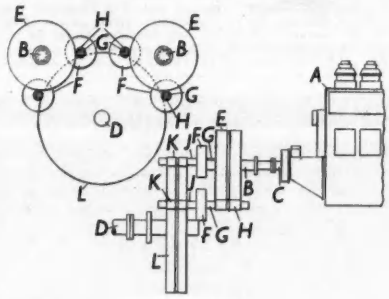
No. 744,029

Sealing between the rotating shaft *A* and the stationary housing is achieved by a carbon nose *F* running against the highly finished surface of the member *B*. This carbon nose will be referred to as the rotating seal member. Sealing along the shaft *A* is accomplished by the synthetic elastic member or sleeve *G*. This material is made resistant to the halogen refrigerants, ammonia and oil. The synthetic material preferably is polymerised chloroprene or the copolymer of acrylic nitrile and butadiene. Any other synthetic material that is flexible and has similar resistant properties may be employed. The flexible member *G* comprises a cylindrical portion *H* that surrounds the shaft and seals it along the shaft. A conical portion *J* extends from the cylindrical portion *H* preferably at an angle of about 15 deg. A flange *K* is preferably at right angles to the cylindrical portion. Another flange *L* extends from the end of the conical portion *J*. The flange *L* of the sleeve is held against the back of the rotating seal *F* by a shell *M*. Spring *N* forces shell *M* toward member *F*, thereby compressing flange *L* to seal securely the space between members *F* and *M*. The flexible sleeve *G* is held against the shaft *A* by a tight-fitting collar *O*. End motion of the shaft within the seal housing is accommodated by putting the conical portion *J* of the elastic member in tension or compression. The tapered ferrule member *P* supports the sleeve in such a way as to prevent it from being damaged by high pressure. Driving of the rotating seal member *F* is effected by two protrusions at 180 deg. in the inside diameter of the shell which fit into matching indentations in the outside diameter of the rotating seal. The shell in turn is driven by upstanding lugs on the collar, which fit in slots in the end of the shell. These slots are proportioned to allow for end motion of the shaft. If desired, other suitable connecting means allowing for the end motion of the shaft may be employed.—*January* 25, 1956.

MARINE ENGINEERING

745,229. May 6, 1953.—SHIP-PROPELLING SPEED-REDUCTION GEAR, The Fairfield Shipbuilding and Engineering Company, Ltd., Govan, Glasgow, S.W.1. (*Inventor: Allan William Davis.*)

Referring to the drawing, two side-by-side diesel oil engines *A* are used, each having a capacity of 2500 b.h.p. Only one of these engines is shown in the right-hand view, but two shafts *B* are shown in the left-hand view, which are flange-jointed extensions of the engine crankshafts *C*. These engines drive a single propeller shaft *D* through a speed-reduction unit. This unit includes a pair of large primary gearwheels *E* which, in the example, are connected directly to the extension shafts *B* and driven by the respective engines at a speed of say 250 r.p.m. The unit includes four fluid slip couplings *F*, each a hydraulic coupling designed to transmit 1250 h.p. at an input speed of 1650 r.p.m. The pump wheel shaft *G* of each coupling is connected to a primary pinion *H* which meshes with one of the primary gearwheels *E*, there being two pinions *H* to each gearwheel. The turbine-wheel shaft *J* of each coupling is connected to a secondary pinion *K*, so that in the speed-reduction unit there are four of these pinions *K* in all. These secondary pinions all mesh with a large secondary gearwheel *L* on the propeller shaft *D*. This secondary gearwheel is about twice as large in diameter as the primary gearwheel. The overall arrangement of the speed-reduction unit is such that the secondary gearwheel is rotated at 110 r.p.m, the propeller shaft



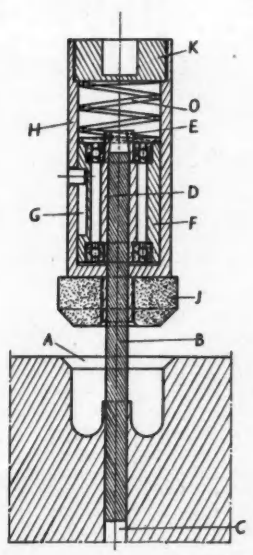
No. 745,229

transmitting 5000 s.h.p. at this speed to the propeller. The pinions and gearwheels are all of the double helical type. A feature of the speed-reduction unit is the freedom allowed its designers to divide the load from a large driving gearwheel to the larger driven gearwheel between two or more lines of transmission, each incorporating its own fluid coupling, so as to maintain the size of each of these couplings within practical limits. An arrangement whereby the fluid couplings are operated at high speeds also contributes proportionately to minimise the coupling size.—*February* 22, 1956.

TOOLS AND WORKSHOP APPLIANCES

745,300. April 17, 1953.—GRINDING APPARATUS FOR TRUING VALVE SEATS, Armand Paul Soulet, Rue de Foulquier, Realmont (Tarn), France.

In the drawing, the valve grinding apparatus is shown on the valve seat *A* to be trued. Over the guiding rod *B* fitted in the valve stem hole is placed a friction sleeve *D* the upper end *E* of which is frusto-conical and is wedged over the end of the guiding rod. A second cylindrical sleeve *F* is revolubly mounted on the sleeve *D* on two ball bearings. The outer sleeve *F* has in it a longitudinal groove G. Around the sleeve *F* is fitted a slidable



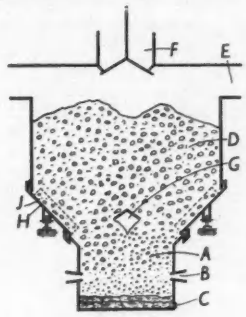
No. 745,300

cylindrical body *H* over the end of which is screwed the grinding wheel *J*, the cylindrical body being provided on its inner surface with a stud engaging the groove *G*, so as to constrain the cylindrical body to rotate in unison with the sleeve. The cylindrical body is closed at its upper end by a plug *K* provided with a six-sided depression while a spring is fitted between the plug and the upper terminal surface of the outer sleeve *F*. By connecting the cylindrical body with the driving means the cylindrical body and the grinding wheel will revolve in unison with the sleeve *F*. When pressure is exerted through the driving means, the spring is compressed and the cylindrical body slides longitudinally of the sleeve *F* so as to bring the grinding wheel into contact with the seat *A*. When the pressure on the spring is released, the wheel moves away from the seat under the action of the spring and it is consequently possible to stop the grinding wheel without it being in contact with the valve seat.—*February* 22, 1956.

FURNACES

744,655. April 8, 1952.—LOW SHAFT FURNACES, Ko-We Niederschachtofen G.m.b.H., Karlsruhe (Baden), Germany. (*Inventors: Heinrich Kopperberg and Werner Wenzel.*)

The low shaft furnace *A* shown in the drawing has blast nozzles *B* and tap hole *C*. The upper portion *D* of the furnace has a cross sectional area considerably greater than that of the hearth. *E*



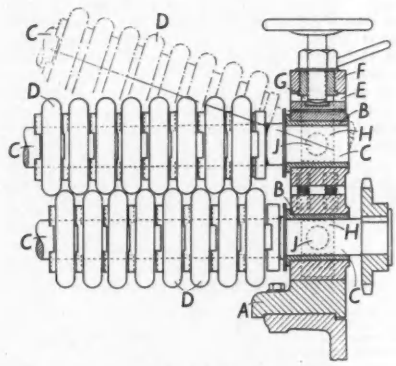
No. 744,655

represents the gas outlet and *F* the charging hopper, while *G* is a central fixed abutment for delaying the descent of the central portion of the charge. The downwardly tapering conical central part *H* of the shaft wall is rotatable, and carries projecting plates *J* for agitating the charge, and this part of the wall is slowly rotated during operation of the furnace.—*February* 8, 1956.

MACHINE TOOLS

745,533. January 27, 1953.—MACHINES FOR THE CORRUGATION OF METAL SHEETS, Frank Morris Gilbert, Gillwood Engineering Works, Canal Parade, Cardiff.

The invention concerns improvements relating to machines in which the forming rolls can be swung about a pivot, and refers more particularly to the bearings in which these rollers are mounted. It has for its object to provide a simple and efficient arrangement for swinging the spindles of the forming rolls, to facilitate their change or replacement.



No. 745,533

In the drawing only one set of bearings is shown, the bearings at the other end of the spindles being of the same construction. The pedestal *A*, carrying the bearings *B* for the spindles *C* on which the forming rolls *D* are mounted, is formed with an open ended slot *E*, having the usual cap *F* to close it. Down the two sides of the bearing bracket are formed the slides *G* in which are mounted the slippers *H* having bearings formed in them, for the trunnions *J*, which are provided on the sides of the bearings *B*, for the spindles of the forming rolls, so as to allow their being moved as shown into the dotted position. The bearings in which the spindles of the forming rolls are mounted are pivoted in the slippers *H* in the bearing pedestal *A*, and when it is desired to change the forming rolls or to vary their centres as described in the earlier Specification No. 736,112, the spindle, together with the bearing *B* on one end of it, is lifted out of the bearing pedestal, thus allowing it to be swung about the trunnions *J* on the opposite bearing, and so allow the alteration to the forming rolls or their changing, without removing the spindle from the machine. In a modification of the invention, instead of the trunnions being formed on the bearings *B*, they may be formed on the slippers *H* with bearings formed in the sides of the bearing members.—*February* 29, 1956.

Launches and Trial Trips

KAITOA, cargo ship ; built by Henry Robb, Ltd., for the Union Steam Ship Company of New Zealand ; length between perpendiculars 290ft, breadth moulded 43ft, depth moulded to upper deck 19ft 6in, deadweight 3030 tons on 17ft 3in mean draught, speed 11 knots ; ten 5-ton derricks, ten electric winches, three 114kW diesel-driven generators ; two British Polar six-cylinder diesel engines, 1700 b.h.p. at 220 r.p.m. Launch, February 28th.

NORMAN PRINCE, cargo passenger liner ; built by the Burntisland Shipbuilding Company, Ltd., for Prince Line, Ltd.; length between perpendiculars 313ft, breadth moulded 46ft 3in, depth moulded to shelter deck 27ft 9in, deadweight 3440 tons, draught 19ft 4in ; twelve passengers ; three holds, one 25-ton and six 5-ton derricks, steam-driven deck machinery, two 45kW steam-driven generators ; Ailsa-Doxford oil engine, equipped to burn heavy fuel, three cylinders, 2300 b.h.p., two multitubular boilers. Trial, February 17th.

EDEN, cargo and passenger liner ; built at Belfast by Harland and Wolff, Ltd., for Royal Mail Lines, Ltd.; length overall 444ft 6in, length between perpendiculars 415ft, breadth moulded 58ft 6in, depth moulded to shelter deck 38ft 4in, gross tonnage 7790 ; twelve passengers ; two complete steel decks, eight watertight compartments, four main cargo holds, one 30-ton, four 10-ton and eight 5-ton derricks, electric deck machinery ; three 150kW diesel-driven generators ; Harland and Wolff, single-acting, opposed piston, oil engine, six cylinders, 620mm diameter by 1870mm combined stroke, 115 r.p.m. Trial, February 1st.

PANAGHIA, oil tanker ; built by the Furness Shipbuilding Company, Ltd., for Porto Alegre Compania Naviera S.A., Panama ; length overall 593ft 2in, length between perpendiculars 560ft, breadth moulded 80ft, depth moulded 42ft 3in, draught summer freeboard 32ft 4in, deadweight 24,940 tons, loaded trial speed 14½ knots ; twenty-seven cargo oil tanks, one main cargo pump room, three 1000 tons per hour turbo-driven centrifugal cargo oil pumps and three 150 tons per hour vertical duplex stripping pumps ; two 325kW turbine-driven generators, one 75kW diesel-driven generator ; one set of Richardson Westgarth double reduction geared turbines, normal power 7300 s.h.p. at 100 propeller r.p.m., maximum power 8200 s.h.p. at 104 propeller r.p.m., steam supplied at 450 lb per square inch and 750 deg Fah. by two Foster Wheeler boilers. Trial, February 21st.

H.M. TUG CONFIANCE, built by A. and J. Inglis, Ltd., for the Admiralty ; length overall 154ft 9in, length between perpendiculars 140ft., breadth moulded 35ft, depth moulded 16ft, displacement loaded 760 tons, draught loaded 11ft, speed running free 13 knots ; two monitors served by a 150 tons per hour salvage and fire pump, two 30 tons per hour bilge and fire pumps, one portable diesel-driven fire pump ; two 100kW diesel-driven generators, one 35kW auxiliary diesel-driven generator ; four Paxman 12 YHAXM diesel engines of 1600 total s.h.p.; drive two Stone Kamewa controllable pitch propellers through Twiflex couplings and two Modern Wheel Drive reduction gearboxes. Accepted for service March 27th.

Catalogues and Brochures

MICROMATIC HONE CORPORATION, 8100, Schoolcraft Avenue, Detroit, 38, Michigan.—Leaflet giving details of a film entitled "Progress in Precision," dealing with "generation of precision functional surfaces."

BROOKS AND WALKER, Ltd., 47, Great Eastern Street, London, E.C.2.—Illustrated catalogue dealing with C. A. Gray "Ritefeel" vernier gauges and internal micrometers, designed for precision measuring instruments.

MORTIMER ENGINEERING COMPANY, 210, Acton Lane, Harlesden, London, N.W.10.—Illustrated catalogue entitled "Ravensburg Faceplate Lathes on Baseplate," showing design, applications and technical data.

IMPERIAL CHEMICAL INDUSTRIES, Ltd., Metals Division, P.O. Box 216, Birmingham.—Volume 1, Number 5, November 1955, Titanium abstract bulletin, a summary of published information on titanium and its alloys.

ELECTROPOWER GEARS, Ltd., Kingsbury Works, Kingsbury Road, London, N.W.9.—Leaflet dealing with type "Slo-Rev" "ESRI/V6," "ESRVI/V6," and "ESRV2/V6" geared motors and speed reducers.

THE INCANDESCENT HEAT COMPANY, Ltd., Cornwall Road, Smethwick, Birmingham.—Leaflet giving details of continuous annealing and galvanising plant for the galvanising of both mild and high-carbon steel wire.

THE HOFFMANN MANUFACTURING COMPANY, Ltd., Chelmsford, Essex.—Illustrated brochure giving technical details of parallel roller bearing axleboxes for railways. Instructions for assembly and maintenance are included.

AVICA EQUIPMENT, Ltd., Mark Road, Hemel Hempstead, Hertfordshire.—Brochure dealing with the development of high-pressure swivel pipe couplings, or rotary "joints," which can be installed in rigid piping systems.

CHARLES S. MADAN AND CO., Ltd., Vortex Works, Altrincham.—Illustrated catalogue describing the "Madan" "airhydropump," hydraulic control valves, special testing equipment and technical data, with conversion tables, &c.

CENTRAL FILM LIBRARY, Central Office of Information, Norgeby House, 85, Baker Street, London, W.1.—Catalogue entitled "Films for Industry," giving details of 16mm films for industrial users for 1956–57, price 2s.

FOSTER TRANSFORMERS, Ltd., South Wimbledon, London, S.W.19.—List No. 1340, dealing with fixed-location, totally enclosed and shell-case, low-voltage transformers, and list No. 1590, dealing with off-circuit tapping switches.

THE HOYT METAL COMPANY OF GREAT BRITAIN, Ltd., Deodar Road, Putney, London, S.W.15.—Illustrated brochure dealing with "Kirksite" "A," the modern alloy for the production of drop hammer and press tools, forming dies, &c.

GODFREY CUTTING JETS COMPANY, Ltd., 173, Downhills Way, Tottenham, London, N.17.—Publications giving details of universal and automatic flame-profiling machine, Model 64, and mobile gas-cutting machines, Models 74 and 74b.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Sat., April 21st.—OXFORD, READING AND DISTRICT BRANCH : Y.M.C.A., 10, George Street, Oxford, "Applications of Metal Rectifiers," 6.30 p.m.

AUSTRIAN INSTITUTE

To-day, April 20th.—28, Rutland Gate, London, S.W.7, "The Influence of Structural Ordering on the Properties of Metallic Materials," E. Schmid, 6.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., April 25th.—London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1, "Radio and Television Interference—Its Growth and Effects," M. Smith, 6.30 p.m.

CHADWICK PUBLIC LECTURES

Thurs., April 26th.—Royal Society of Health, 90, Buckingham Palace Road, London, S.W.1, "The Centenary of London's Main Drainage System," J. Rawlinson, 5.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, April 20th.—BATH AND BRISTOL CENTRE : Royal Hotel, Bristol, Annual General Meeting and Film Show, 7 p.m.
Thurs., April 26th.—NOTTINGHAM CENTRE : E. Midlands Electricity Board, Smithy Row, Nottingham, "Outdoor Illuminations," H. Carpenter, 6 p.m.
Fri., April 27th.—BIRMINGHAM CENTRE : "Regent House," St. Phillip's Place, Colmore Row, Birmingham, "Blackpool Illuminations," H. Carpenter, 6 p.m.

INCORPORATED PLANT ENGINEERS

Tues., May 1st.—LONDON BRANCH : Royal Society of Arts John Adam Street, Adelphi, Strand, W.C.2, "Repairs of Cracked Castings—The Modern Methods," N. Tinwell, 6.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Tues., April 24th.—COVENTRY SECTION : Room A5, Technical College, Coventry, Annual General Meeting, followed by a Film Show, 7.30 p.m.
Wed., April 25th.—BIRMINGHAM BRANCH : James Watt Memorial Institute, Great Charles Street, Birmingham, Annual General Meeting, 7.15 p.m.——LONDON BRANCH : Waldorf Hotel, Aldwych, W.C.2, Annual General Meeting, "Casting of a Large Winding-Drum Check," A. W. Bartlett, 7 p.m.
Thurs., April 26th.—BEDS AND HERTS SECTION : K. and L. Steelfounders and Engineers, Ltd., Letchworth, Annual General Meeting, 7.30 p.m.
Sat., April 28th.—BRISTOL AND WEST OF ENGLAND BRANCH : Grand Hotel, Bristol, Annual General Meeting, 3 p.m.

INSTITUTE OF FUEL

Thurs., April 26th.—E. MIDLAND SECTION : Gas Showrooms, Lecture Theatre, Nottingham, Annual General Meeting, followed by a Film Show, 6.15 p.m.
Tues. and Wed., May 1st and 2nd.—Church House, Westminster, London, S.W.1, Opening Conference of a Special Study of "Domestic Heating in the United Kingdom—Present and Future," 10 a.m.

INSTITUTE OF MARINE ENGINEERS

Mon., April 23rd.—MERSEYSIDE AND N.W. SECTION : Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "The Carriage of Edible Oil and Similar Bulk Cargoes," John Wormald, 6.30 p.m.——STUDENT LECTURE : 85, Minories, London, E.C.3, "Fundamental Principles of Marine Instrumentation," F. P. Rout, 6.30 p.m.
Tues., April 24th.—85, Minories, London, E.C.3, Annual General Meeting, 5.30 p.m

INSTITUTE OF METALS

Wed., April 25th.—4, Grosvenor Gardens, London, S.W.1, "The Beginnings of Metallography," Cyril S. Smith, 6.45 p.m.

INSTITUTE OF PHYSICS

Fri., May 4th.—NON-DESTRUCTIVE TESTING GROUP : 47, Belgrave Square, London, S.W.1, a Symposium on "Principles of Penetrant Methods," H. L. Carson, W. G. Cook and R. Schnurmann, 6.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., April 26th.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "The Use of Radioactive Techniques in Refrigeration Engineering," D. B. Smith, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., April 23rd.—SCOTTISH CENTRE : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Centre Annual General Meeting, 7.30 p.m.
Tues., April 24th.—N.E. CENTRE : Three Tuns Hotel, Durham City Centre, Annual General Meeting, 7 p.m.
Mon., April 30th.—N. REGIONAL CENTRE : Victoria and Station Hotel, Preston, Centre Annual General Meeting, 7.30 p.m.

INSTITUTE OF WELDING

To-day, April 20th.—BIRMINGHAM BRANCH : Grand Hotel, Birmingham, Annual General Meeting and Film Show, 7.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Tues., April 24th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Hydrostatic Transmission for Tractors," H. J. Hamblin, 6 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., April 24th.—AIRPORT MEETING : Great George Street, Westminster, London, S.W.1, "The Investigation, Design and Construction of Paya Lebar Airport, Singapore," J. J. Bryan, 5.30 p.m.
Thurs., April 26th.—RAILWAY MEETING : Great George Street, Westminster, London, S.W.1, Informal Discussion, "Mechanised and Mobile Gang Maintenance of Track," J. R. Hammond, H. H. Robinson and I. G. White, 5.30 p.m.
Fri., April 27th.—YORKSHIRE ASSOCIATION : Royal Victoria Hotel, Sheffield, Annual General Meeting, 6.15 p.m.
Tues., May 1st.—HYDRAULICS MEETING : Great George Street Westminster, London, S.W.1, "Pumping Problems : Present and Future," Herbert Addison, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, April 20th.—EDUCATION DISCUSSION CIRCLE : Savoy Place, London, W.C.2, Discussion on "Theories of Electromagnetic Induction," opened by G. W. Carter, 6 p.m.
Mon., April 23rd.—RADIO AND TELECOMMUNICATION SECTION : Savoy Place, London, W.C.2, Informal Evening on "Electronics and Automation" ; Talk by G. W. A. Dummer, "Automatic Assembly Systems for Electronic Equipment," with Films and Demonstrations, 5.30 p.m.
Wed., April 25th.—SUPPLY AND MEASUREMENT SECTIONS : Savoy Place, London, W.C.2, "Physical Properties and Impulse Strength of Paper," H. C. Hall and E. Kelk ; "The Impulse Strength of Lapped Impregnated Paper Dielectric," H. C. Hall and D. J. Skipper ; "Breakdown Under Impulse Voltages of Solid and Liquid Dielectrics in Combination," W. G. Standring and R. C. Hughes, 5.30 p.m.
Thurs., April 26th.—ORDINARY MEETING : Savoy Place, London, W.C.2, Kelvin Lecture, "Radio Astronomy," A. C. B. Lovell, 5.30 p.m.
Fri., April 27th.—JOINT MEETING : Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, Graham Clark Lecture, "The Impact of Engineering on Society," Sir Maurice Bowra, 5.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Tues., April 24th.—SCOTTISH BRANCH : Building Centre, 425, Sauchiehall Street, Glasgow, C.2, Annual General Meeting, "Heating of Large Chambers," 7 p.m.
Wed., April 25th.—LIVERPOOL AND DISTRICT BRANCH : College of Buildings, Clarence Street, Liverpool, Annual General Meeting, 6.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, April 20th.—GENERAL MEETING IN CONJUNCTION WITH THE EDUCATION GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, "An Approach to the Technique of Graduate Training in Industry," D. L. Marples, J. F. A. Radford and J. L. Reddaway, 5.30 p.m.
Tues., April 24th.—GENERAL MEETING IN CONJUNCTION WITH THE INTERNAL COMBUSTION ENGINE GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, "Crankcase Explosions : An Investigation into Some Factors Governing the Selection of Protective Devices," H. G. Freeston, J. D. Roberts and A. Thomas ; "Crankcase Explosions : Development of New Protective Devices," W. P. Mansfield, 5.30 p.m.
Thurs., April 26th.—SPECIAL MEETING : 1, Birdcage Walk, Westminster, London, S.W.1, Corporate Members only, 5.30 p.m. —N.W., A.D., CENTRE : Royal Hotel, Bristol, "Ball and Roller Bearing Development," M. J. Knaggs, 6.45 p.m.
Fri., April 27th.—JOINT MEETING : 1, Birdcage Walk, Westminster, London, S.W.1, Graham Clark Lecture, "The Impact of Engineering on Society," Sir Maurice Bowra, 5.30 p.m.
Tues., May 1st.—JOINT MEETING : Institution of Civil Engineers, Great George Street, London, S.W.1, "Pumping Problems, Present and Future," Herbert Addison, 5.30 p.m.

INSTITUTION OF NAVAL ARCHITECTS AND INSTITUTE OF MARINE ENGINEERS

Sat., April 28th.—SOUTHERN JOINT BRANCH : Visit to Cowes, including a paper, "Shipbuilding at Cowes," J. A. Milne, 2 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Mon., April 23rd.—N.W. REGION : College of Technology, Sackville Street, Manchester, "The Factory Acts and How They Affect Engineering Establishments," Sir George Barnett, 6.30 p.m.
Tues., April 24th.—LONDON GRADUATE SECTION : 10, Chesterfield Street, London, W.1, "The Finishing of Work by Polishing and Plating," H. Cann, 7.15 p.m.
Wed., April 25th.—WOLVERHAMPTON SENIOR AND GRADUATE SECTIONS : Technical College, Wolverhampton, "Work Study and the Production Engineer," J. V. Connolly, 7.15 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Thurs., April 26th.—11, Upper Belgrave Street, London, S.W.1, "Design and Construction of the Printing Works at Debden," Sir Howard Robertson, Ove Arup, R. S. Jenkins and H. F. Rosevear, 6 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, April 20th.—INFORMAL MEETING : Pepys House, 14, Rochester Row, London, S.W.1, "Sensitive Instruments used by Faraday and Unchanged in Present Everyday Use," H. J. N. Riddle, 7 p.m.
Mon., April 23rd.—SHEFFIELD AND DISTRICT SECTION : Royal Victoria Hotel, Sheffield, Visit of Officials from Headquarters, Presidential Address, "Dams," G. M. Binnie, 7.30 p.m.
Tues., April 24th.—N.W. SECTION : Engineers' Club, Albert Square, Manchester, Visit of Officials from Headquarters, Presidential Address, "Dams," G. M. Binnie, 7.30 p.m.
Fri., April 27th.—Connaught Rooms, Great Queen Street, Kingsway, London, W.C.2, Annual Dinner, 6.45 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, April 20th.—Mining Institute, Newcastle upon Tyne, "Geared-Diesel Marine Machinery with Particular Reference to the Performance of Two Installations of Different Types," J. Calderwood, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., April 24th.—SECTION LECTURE : 4, Hamilton Place, London, W.1, "The Development of Helicopter Transport," R. H. Whitby, 7 p.m.

ROYAL SOCIETY OF ARTS

Thurs., April 26th.—COMMONWEALTH SECTION : John Adam Street, Adelphi, London, W.C.2, "The Snowy Mountains Scheme," C. M. Gray, 5.15 p.m.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon., April 23rd.—The University, St. George's Square, Sheffield, Film Show, 7.30 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., April 24th.—JOINT MEETING WITH CONTROL SECTION : Manson House, 26, Portland Place, London, W.1, "Dynamic Characteristics of Some Neutralisation Processes and of Glass pH Electrodes," H. Kramers, 6.30 p.m.